

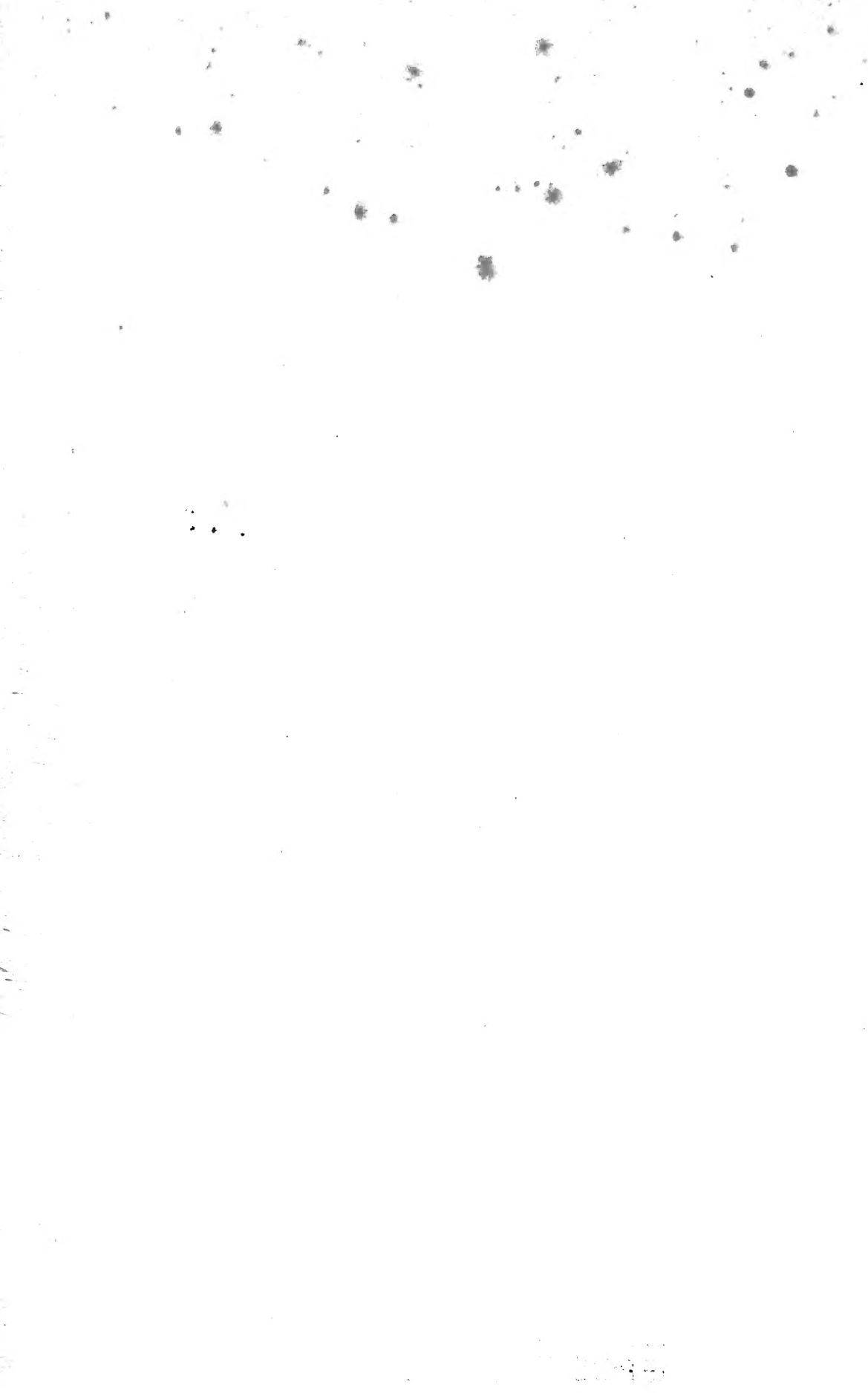




Museum Victoria



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RECORDS
OF THE
GEOLOGICAL SURVEY

OF
INDIA.



VOL. XI.

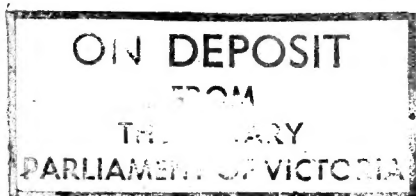
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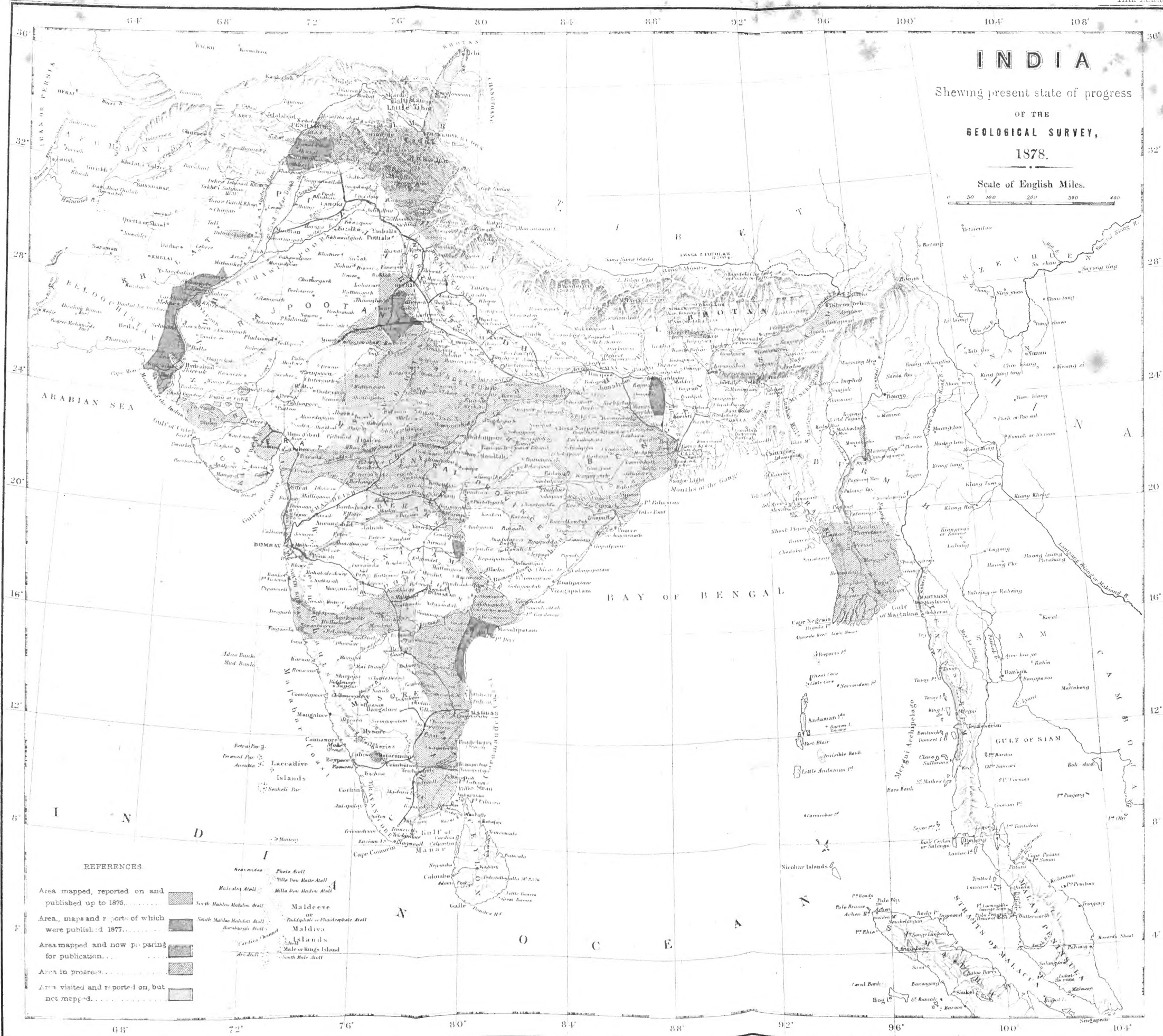
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Outline and Boundaries by James M. Dalziel. Hills by Francis J. T. Walsh.
Engraved under the Superintendence of C. R. Goud.

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Compiled by J. O. S. Jones

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.]

1878.

[February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1877.

New ground.—The field-work of the Geological Survey of India is of two kinds: the preliminary exploration of ground regarding which our knowledge is either a blank or exceedingly vague, and the more detailed study of rocks the general features of which have been laid down. The latter is essentially the more difficult task, and, within certain limits, the more interesting to the geologist, as requiring the more exact application of the guiding principles of his science, and as affording the better opportunity of testing and defining those principles themselves. The attractions of the former, both to the worker and the looker-on, are its rapidity and the more easy attainment of the sensation of adding something to our store of knowledge. In the progress of the Survey, the proportions of these two kinds of work undergo a constant change; but we are still far from the state of having no new ground to explore. During the past season two such blanks have been approximately filled in.

I am glad to announce that the principal of these reclaimed territories is in the higher Himalaya. Hitherto our work in this most interesting region has been in a manner occasional. The circumstance of my connection with the College at Roorkee for some years placed me within easy reach of the lower Himalaya, and the results of four seasons' work were published in 1864 (Memoirs, G. S. I., vol. III). Dr. Stoliczka's zeal for great undertakings led him early to urge the exploration of Western Tibet. The result of his observations in that difficult region during the summers of 1864 and 1865 were published in vol. V of our Memoirs, and were supplemented by his notes on his last fatal journey to Kashgar in 1873 (Records, G. S. I., vol. VII). The urgent demand for coal in connexion with the Northern Bengal Railway led to Mr. Mallet's deputation in 1873 to examine the Damúda rocks discovered in 1849 by Dr. Hooker at the base of the Sikkim Himalaya. Mr. Mallet's observations on this fringe of the mountain region were published in vol. XI of the Memoirs. The foregoing accounts, together with the observations by Captain R. Strachey, R.E., in Kumaun and Central Tibet, and published with a map in the Quarterly Journal

of the Geological Society, London, vols. VII and X (1851 and 1854), constituted so far the only definite materials for a geological map of the mighty Himalaya. In 1875-76 the examination of the outer tertiary zone and adjoining rocks was carried up to the Jhelum (Records, vol. IX); and in continuation of this work, Mr. Lydekker, during the past season, has made an extensive exploration of the mountains north and south of the Kashmir Valley and in the upper basin of the Chenáb.

That so little should have been known regarding the geology of such an attractive spot of earth as Kashmir, is a fair indication of the difficulty of the ground. Flying observations have of course been recorded, and some bold speculations based thereon; but these contribute little towards a definite knowledge of the rock-structure. The presence of carboniferous strata was long since observed, and the extensive occurrence of eruptive rocks has been prominently noticed; but the relations of all these to the preponderating mass of contiguous unfossiliferous rocks have remained unknown. Mr. Lydekker shews that the Kashmir area is a compressed synclinal ellipse, on the pattern of the larger features defined by Stoliczka in the Tibetan region, but containing, so far as observed, no rocks younger than the trias. The slates of the Pir Panjál are shewn by connected observations to be the equivalents of the Silurian and *infra*-Silurian strata of the Tibetan sections. After some hesitation, Mr. Lydekker decided that the trappean rocks must belong to a period of local eruption in the upper part of the Silurian series. Although very frequently observed in abrupt and troubled contact with the carboniferous rocks, they were never seen to penetrate these strata, or above them.

On the south-eastern prolongation of the Kashmir synclinal, but separated from it by a mass of metamorphic rocks in Kistwár and Badriwár, there is in the Pángi district, on the upper Chenáb, a smaller synclinal ellipse, in which only the Silurian slates have been found. This basin is cut off to the south-east by the gneissic masses of Lahul. This feature of longitudinal structure—the recurrence of basins of depression along the same mountain zone—is also a character of the more central Himalayan regions, where the great basin of Spiti and Zaskar is cut off from the very similar basin of Hundes, on the same strike, by the metamorphics of North Bisáhir. The fact seems to preclude the suggestion that has been made, that these basins are in some degree aboriginal with relation to the included formations.

The relations of the gneissic series are still the most obscure point in these mountain-sections. Mr. Lydekker feels compelled to adopt the view that the Pir Panjál range is, on the whole, a great folded anticlinal flexure, having a core or axis of gneiss, the whole stratified series on the outer (south-west) side being inverted. In this arrangement, if the gneiss is even approximately conformable with the slate series (as this view implies and as is apparently the case), the actual position and structure of this gneiss and of the contiguous slates must be due to acts of disturbance common to both; for, it would seem impossible to produce the great fold, and the inversion of the strata on the south-west, if the gneiss had pre-existed as a ridge in this position. Again, there are clear sections shewing the slate series to pass transitionally (by interstratification)

downwards into crystalline schist and gneiss, which certainly implies that the conversion of this gneiss is of later date than the deposition of the slates. Yet there are observations in this region shewing most indubitably that, during the deposition of the slates, a gneiss was undergoing violent denudation, and at no great distance: throughout a considerable thickness of strata in Pángi, large blocks of gneiss are imbedded in the unaltered slates. From the circumstances Mr. Lydekker conjectures that they were ice-borne; but, however this may be, the immediate difficulty is, that they seem to be of Himalayan gneiss, as they resemble it, and are not like any known gneiss of the nearest region to the south. If they were derived from any gneiss now exposed in the Himalaya, we may surely say that it must be of very different age from the gneiss conformably underlying and transitional with these same slates; and that the unconformity between the two series must, at least originally, have been of a very striking character, so that the non-recognition of such a feature would vitiate any independent interpretation of the rock-structure. The question radically affects the view to be taken of the mountain-formation; but we are still in uncertainty regarding it, no such distinction having been as yet detected in the gneissic masses of this region. The great gneissic mass of the Zaskar range is certainly to some extent composed of a gneiss associated with the slates; the so-called "central gneiss" has also been provisionally identified in it; but no mineralogical criterion or stratigraphical demarcation has as yet been attempted between them. An account of Mr. Lydekker's observations is published, with a skeleton map, in the current number of the Records.

In this connection I am glad to have to notice the work of a geologist who is not on the staff of the Survey, although his observations have been published in our Records for the past year. Workers for love of geology have become so rare in India that the appearance of one is quite an event; and Colonel McMahon's paper is in good form, representing much hard work in the field and the study, put together rationally, without random speculation. His map of the Simla region indicates a clue to the structure of the most difficult region of Himalayan geology, and an interpretation that may prove of great service is suggested. The ground sketched by Mr. Lydekker, although adjoining the great fringing zone of tertiary rocks, is strictly on the prolongation of the great central Himalayan range, and the structure is on a reduced scale of the same type. The Simla region is quite different: it belongs to that broad area of lower mountains which to the east of the Sattlej separates the snowy range from the plains, and is made up of metamorphic and slaty rocks in a very irregular and incomprehensible mode of distribution. In the midst of the slate series there is one well-marked group, affording the most certain guide to the disturbance of the strata. Colonel McMahon has mapped its outcrop over an extensive tract of rugged mountains. He has also indicated for this region a probable solution of the difficulty noted in Mr. Lydekker's work regarding the gneissic rocks. He shews that the massive gneiss forming several prominent ridges in the lower mountains must be the same as the "central gneiss" of the main range; he describes the upper members of the slate series to be so related to this gneiss as to involve

the total overlap of the lower part of the series, and therefore complete unconformity to the gneiss; subsequent metamorphic action, largely affecting the slate series itself, especially at the contact with the older gneiss, has so obscured the junction as to make the exact definition of it a matter of great difficulty.

The other newly reclaimed area is in Peninsular India. The wide tract (some 300 miles long) between the Máhanadi and the lower reaches of the Godávari, although completely surveyed topographically, is one of the least frequented regions of the Peninsula. It is a wild hilly country entirely occupied by primitive tribes and petty tributary states. From the condition of adjoining areas we could only conjecture that it was occupied by Vindhyan and gneissic rocks; and such has proved to be the case. During the past season, Mr. Ball made an extensive circuit over that ground, and an account of his observations has already been published, with a sketch-map, in the Records.

On the coast side there is a broad mountainous belt (130 miles wide), some summits exceeding 5,000 feet in elevation. It is known on both sides to be formed of crystalline rocks, and is probably so throughout. West of this there is an extensive upland, also largely formed of gneissic rocks, but upon which there stand two or more scarped plateaus of flatty bedded sandstone, the principal being that of Nowagarh-Khariál. Further west there is the wide expanse of lower ground formed of the shales, limestone and sandstones, occupying the plains of Chhattisgarh and the upper valley of the Máhanadi, and stretching southwards to the more elevated land about Bastar. These latter rocks have for long been recognised as of lower Vindhyan age; but Mr. Ball thinks that the Khariál sandstones may represent upper Vindhyan, as they are locally underlaid by shales very like those of the Chhattisgarh plains. As yet no upper Vindhyan have been identified south of the Son-Narbada valley. That these formations should still have to be classed as azoic, is a recurring cause of surprise and disappointment to geologists in India.

In the valley of the Tel and elsewhere in low ground south of the Máhanadi, Mr. Ball observed several distant outliers of the Talchir deposits; while on the highest summits visited, both of detached hills and within the range of the Eastern Ghâts, he found the massive rock-laterite, giving a plateau character to the otherwise serrated mountain-features. This high-level laterite forms, throughout the whole of middle and northern India, a thick (50 to 100 feet) level capping to most of the highest summits, whatever may be the structure of the underlying rocks, and has the same composition, whatever may be that of the rocks it rest upon, so that it cannot in any way be derived from their transformation. Its mode of origin is still one of the greatest puzzles in Indian Geology.

During a short visit to Naini Tal in September, Mr. Ball made some observations regarding the numerous lakes of that neighbourhood.

Mr. Hacket's work in Rajputana must also rank as in new ground. He has carried his observations to some distance south of Ajmir, where he obtained a fuller section of the metamorphic rocks transitionally underlying his Arvali series. In the northern sections, about Alwar and Biána, these transition beds

seem to be locally wanting. Altogether the study of these highly altered and disturbed formations is most intricate, and it is likely to be long before a connected and satisfactory account of them can be given.

Mr. Hacket confirmed in other localities Mr. Blanford's discovery of Vindhyan strata to the west of the Arvali range, but in a more easterly position, resting quite flatly close to the main series of gneissic rocks; so that the Vindhyan formation must be altogether younger than the Arvali mountain-system.

No rocks but the quartzites and other strata of the Arvali series were found in the vicinity of the famous Sámbar salt-lake; and no observation was made suggesting any connection of the salt with these rocks.

Gondwána formation.—The recognition of the Karharbári coal-measures as a distinguishable horizon in the lower Gondwána series is an interesting step in our knowledge of these formations. As immediately overlying the Talchírs, these beds have hitherto passed as belonging to the Barákár group, the lowest of the Damuda coal-measures. The first discovery in them of peculiarly triassic plants not found elsewhere, looked at from the point of view of palæozoic affinities for the Damuda flora, suggested that the Karharbári beds should be regarded as above the Damudas. Further collections of fossils made by Dr. Feistmantel, and others presented by Mr. Whitty, the engineer in charge of the extensive mines from which the East Indian Railway is supplied, have not supported this notion. Dr. Feistmantel points out that with those special plants are found the few which most distinguish the Talchírs, and that the affinity is with this bottom group of the Gondwána system, rather than with the Damudas. The position of the field, well out of the Damuda valley, and more analogous to that of the central fields, in which also the coal-measures have hitherto been regarded as Barákár, suggests that these too may be found to present these new palæontological affinities. Dr. Feistmantel reports from Mohpáni that there is some confirmation of this view in the plants he has recently found there. The very close stratigraphical relations of the Satpura coal-measures with the Talchírs in the Betúl field was insisted upon in the last survey of that ground (Records, vol. VIII, p. 65, 1875).

Of our detailed work an interesting area of the Gondwána formations was completed during last season by Mr. Hughes, in extension of his previous work in the Wardha valley, the geological lines being now carried down to the Godávari at and above Sironcha. An important practical result of this work is the accurate demarcation of a considerable area of possibly productive coal-measures in the Nizam's territories about Khaírgura and Tandúr, and again on the Godávari at Sandrapáli. In the former position actual coal crops were found; at the latter the discovery was quite unexpected, as the ground is greatly concealed, but the indications are considered sufficient. Directions are given for the practical exploration of the measures.

Two localities within this area have long been familiar to students of Indian Geology from the fossils they have yielded—the liassic fish remains of Kota and the triassic reptilian bones of Maléri—and on this account special interest attaches

to Mr. Hughes' stratigraphical determinations. The result, whether local or general, has not been confirmatory of the speculations that had been hazarded upon previous knowledge. Partly from the fossils and partly from the mineral aspect of the rocks, it had been thought that the Maléri beds might represent the Panchet group in the lower Gondwána series of Bengal. From the evidence of some plant fossils obtained during the recent survey, it is, however, decided that these deposits must rank as upper Gondwána. As regards the different horizons suggested, according to the European standards, by the fossils from the two localities, Mr. Hughes' description shews that the beds of Maléri and of Kota cannot be distinguished as separable groups, and therefore that the aforesaid fossils must be taken as contemporaneous in India. This fact, and the affiliations suggested by the fossil flora, present altogether a serious puzzle to palæontologists of the rigid school. The question is briefly stated by Mr. Blanford in a note appended to the description of the Kota-Maléri fossils in a recent number of the *Palæontologia Indica*. A map and description of Mr. Hughes' work is published in the current number of the *Records*.

The Kota-Maléri area is part of the continuous spread of Gondwána deposits within the drainage-basin of the Godávari, and hence often spoken of collectively as the Godávari basin or region; but it is only on the lower half of this river itself that these formations occur; the extension above Sironcha is in the valleys of the great tributaries, the Pránhita and Wardha, to where the strata pass under the Deccan trap in the Chánda and Wún districts. The portion below Sironcha is considerably larger than that above it, and Mr. King has been for several seasons engaged in studying this ground. Notices of his discovery of marine beds intercalated with the upper Gondwánas on the seaward margin of the area, were published at the time; and also his description of some small coal basins within or adjoining the main area. A notice of his preliminary observations regarding the whole area was published in the last May number of the *Records*. During the past season Mr. King made further progress in unravelling the intricate relations of these closely connected rock-groups, and is still engaged in carrying on these researches: but it is scarcely to be expected that he can complete so difficult and extensive an investigation within the present field-season.

Mr. Foote has been engaged for several seasons past upon the coastal zone of Gondwána deposits, in continuation of his previous published work on these beds in the area around Madras. During the past season he completed his survey of this ground through the Nellore and Gantúr districts up to the Krishna river, thus bringing his lines into connexion with Mr. King's work in the Godávari district south of Ellore. The deposits which were the special object of his study are very obscurely exposed as irregular patches along the margin of the crystalline rocks forming the low ground from the base of the Eastern Ghâts; and on the east they pass rapidly under the alluvium of the flat seaboard. Mr. Foote has made considerable collections of the mixed marine and terrestrial fossils peculiar to the Gondwána strata in this position. A description of his work is in course of preparation.

Explorations for coal.—In connexion with the Gondwána formation, record should be made of the coal explorations that have been going on for several seasons past in the Sápura basin. They were undertaken by Government at my recommendation, and have been carried out more or less to the extent contemplated, but have proved unsuccessful. The observations and chances upon which these experiments were based have been from time to time explained in the Records, so that a brief recapitulation of the circumstances will now suffice. The only outcrop of the coal-measures on the north side of the Sápura basin of Gondwána rocks is on the Sitariva at Mohpáni. It is there that the structural characters of the outcrop, so close to this obscure main boundary of the basin, should have been practically tested and the continuity of the measures proven. The mining operations there have, however, been hitherto on a very paltry scale, and the work of exploration most inefficiently carried out. The difficulties of the ground are, no doubt, considerable, but not a single trial to the dip of the basin has been carried to the depth at which it could have been expected to touch the coal in the position attempted. The whole ground on the Sitariva is in private hands, and Government could not interfere to insist upon a more effective method of search, so it was reasonably resolved to attempt the exploration of the basin at other less favourable points, where the measures themselves had to be sought for.

In pursuance of this project three classes of trial were indicated. It was shewn that the total cutting off of the Gondwána rocks to the north, along a supposed great fault, was at least not proven; and that therefore it was possible that the coal-measures might in certain positions occur beneath the alluvial area of the Narbada valley. To test this conjecture two borings were made, one at Gadarwára close to the main line of railway, and one at Sukakheri by the side of the branch line, half way to Mohpáni. The former was stopped at a depth of 251 feet, as the tubes could not be forced further, and smaller tubes, to pass down inside the first set, were not then available. The Sukakheri boring was sunk to the depth of 491 feet still in alluvial deposits, chiefly clay; and it is highly creditable to Mr. Stewart, the brace-head man in charge of the work, that with such labour and appliances as he could command he was able to sink so deep. This is a far greater thickness than was at all anticipated for the valley deposits; and the trial has practically answered the question proposed, for it would certainly not pay at present to seek the coal through such a thickness of soft rocks. It is plain, however, that the question whether or not the coal-measures extend in this direction (upon the possibility of which the experiments were undertaken), is not affected by the result.

A second class of trial was based upon the fully proven fact that the thickness and distribution of the upper Gondwána groups are exceedingly irregular. It was thus hoped that the coal-measures might possibly lie at a practicable depth within the basin, in the open valleys of the Dudhi and the Táwa, where the measures, if found, would be free from the many accidents that render the working of them so difficult in the disturbed ground near the boundary. Borings were accordingly put down at Manegáon and at Kháppa in the Dudhi valley. The former was closed at 420 feet, as the depth attained required constant super

vision upon one work. At the close of last working season the Kháppa boring had reached the depth of 720 feet, altogether by hand—another very creditable performance of Mr. Stewart's. Here again the practical question was solved for the present by the mere fact of depth. No change of formation occurred throughout the boring, so the geological information gained is also limited to the bare fact of thickness. As the progress of boring by hand at this depth is so slow and costly, I could not, under the circumstances, recommend the prosecution of the work. Corresponding trials to these were made in the open valley of the Táwa, along the Betúl and Hoshangabad road, at Kesla to a depth of 302 feet, and at the Suktáwa to 241 feet, with the same result.

A third class of experiment lay in the attempt to find the coal-measures in positions corresponding to Mohpáni, close to the edge of the basin. The inducement here is that Talchír beds, which are the most frequent companions of the coal-measures, occur at several places along the margin of the field. The special objections to this position are the frequent presence of trappean intrusions and the great disturbance of the strata. Three borings were put down at Tundni, ten miles west of Mohpáni. Two of them, at depths of 328 and 172, struck trappean and contact-rocks, being evidently on a belt of intrusive action. The third, more to the south, found no change to 243 feet, where the tools stuck fast; but as the dips were high there was no inducement to renew the attempt.

At the western extremity of the field, on the Moran near Lokartalai, some highly carbonaceous outcrops have long since attracted the attention of explorers. A boring put down to the dip of those outcrops, to a depth of 254 feet, has shewn that these coaly bands do not improve underground; and a later discovery of fossil plants in these beds has shewn that they do not belong to the lower Gondwánas. Two other borings were put down at the lowest point of the section, to try the underlying strata; but at depths of 84 and 88 feet (the holes are 60 yards apart across the strike) an intensely indurated sandstone was struck, in which little or no progress could be made. It is almost certainly the contact bed of an intrusive sheet of basalt, the presence of which would indefinitely reduce the prospect of success; so the project was abandoned. This position also is close to the north boundary of the basin and within the zone of special disturbance.

Two other trials of this series remain to be noticed, those close to the patches of Talchír rocks. One on the road from Piparia station to Pachmarhi, within 50 yards of the Talchír outcrop, was sunk to a depth of 285 feet entirely in coarse mottled deposits of the upper Gondwánas, shewing that their junction with the Talchírs must be exceedingly steep, if not faulted, and that the coal-measures, if present, are beyond easy reach. Another trial, now in progress, on the Anjan, close to the road from Bankeri station to Pachmarhi, is also close to an outcrop of Talchírs; it has reached a depth of 186 feet, entirely in mottled sandy clay of the Bágra group.

These trials may be taken as closing for the present the exploration of this region of the basin, unless in immediate continuity of the Mohpáni field on the Sitariva. Should this fail, the nearest prospect is in the Sháhpur field on the south side of the basin.

Punjab.—Mr. Wynne was fully occupied during last season in mapping the structural features of the tertiary basin between the Salt Range and the mountains to the north, and often spoken of as the Potwár, or the Ráwalpindi plateau. It is, on the whole, a broad synclinal, with many subordinate axes of flexure. The changes in composition of these tertiary deposits according to position with reference to the mountain region and to the great river courses, combined with the great disturbance they have undergone, is a constant obstacle to the attempt to trace the zones of contemporaneous strata. To do this with any certainty will be a work of great labour which the Survey is not at present prepared to undertake; yet until this is done, it will be impossible with any nicety to indicate the order of succession of the vertebrate fauna, which forms the chief interest of these formations. The more regular sections of the corresponding deposits in Sind may furnish this important clue to the horizons in the Sub-Himalayan region. A sketch of Mr. Wynne's work, with an outline-map, is given in the Records for last August.

Mr. Theobald has added largely to our collections of fossils from these rocks in the Potwár during the past season; but it is only in an approximate and often doubtful way that the specimens can be assigned to the different horizons: Mr. Theobald reports favourably of the assistance he has received in this work from the apprentice Kishen Singh. A notice of these collections up to date is given by Mr. Lydekker in the current number of the Records.

The post-tertiary deposits of this region offer a study of much interest. They are found resting upon tilted Siwalik strata at very high levels over the actual river courses, so that prodigious denudation must have taken place since they were laid down. There is much evidence to suggest that glacial action took a direct part in the accumulation of some of these deposits.

Sind.—During the working season of 1876-77, Mr. Blanford and Mr. Fedden completed the mapping of Sind, west of the Indus. A considerable portion of the country had been examined in the two preceding seasons, but in several districts the examination had only been partial and preliminary. In the course of the past season Mr. Blanford re-examined the Khirthar range from its northern termination west of Jacobabad to the neighbourhood of Schwan; he then re-mapped the cretaceous rocks in the Laki range south of Schwan, and after completing the geological lines in the Hubb valley, and marching westward along the coast as far as Sonmiani, returned to Calcutta at the commencement of March, to continue his work on the geological manual.

Mr. Fedden, starting from Karáchi, mapped the large tract of country west of the Laki range, from the neighbourhood of Schwan to the sea, an area of nearly 5,000 square miles. The ground had been partially examined before, but the greater portion of the details were completed during the past season. Large additions were also made to the fossil collections previously obtained.

So much of the geology of Sind had been determined in the two previous seasons that no very important additions could be expected. Still several slight, but useful, improvements were effected. The exact relations of the bed of trap

found in the Laki range had remained somewhat doubtful, the country in which the rock occurs being difficult of access, the geology complicated by faults and disturbance, and the topographical map very imperfect. It has, however, now been clearly ascertained that a band of contemporaneous volcanic rock, from 40 to 90 feet thick, intervenes between the base of the Ranikot group (lower eocene) and the cretaceous beds, and there can be no reasonable doubt that this thin lava-flow represents the great mass of the Deccan traps. The geological position of these traps below the eocene group, as inferred from their relations in the lower Narbada (Nerbudda) valley, has thus been confirmed from independent evidence.

The cretaceous beds between Ranikot and Laki have been found to be above 1,000 feet thick, their base not being exposed, and they are sub-divided into three groups marked by differences of mineral character and of fossils. The lowest group is the limestone in which a *Hippurite* was found last year.

In the Laki range and the country around Jhirk and Tatta, the nummulitic Khirthar limestone rests upon the Ranikot group, the latter being about 2,000 feet thick where most fully developed, and overlying the traps and cretaceous beds above noticed. But west of the Khirthar range, in Upper Sind, Mr. Blanford found, in a traverse which he made for a short distance beyond the frontier on the upper Gáj river, a thickness of at least 10,000 feet of beds underlying the Khirthar limestone, and having no resemblance to the rocks in the same position to the south-east. These lower beds on the west of the Khirthar range consist of shales, limestones, and sandstones; and fossils were detected in places throughout the upper 4,000 or 5,000 feet, the lower portion being apparently unfossiliferous. All the fossils found were nummulitic and shewed the rocks to be of eocene age. Somewhat similar beds were observed on the Habb river, where the great mass of Khirthar limestone, so conspicuous throughout the greater part of Sind, completely thins out and disappears in the course of 20 or 30 miles. The calcareous shales and sandy beds which replace the limestone, and the very similar rocks seen beneath the typical Khirthars on the upper Gáj, are identified by Mr. Blanford with the beds which he traversed in Western Makrán, between Gwádar and Jálk, in 1872.

Both Mr. Fedden and Mr. Blanford have found that all the tertiary groups of Sind, although well marked and distinct in places, pass into each other elsewhere, thus repeating, in the extreme west of India, the phenomena already noticed in the Himalayas. It has been found very difficult in many cases to map the distinctions between the different groups. In parts of Lower Sind near Karáchi the Gáj (miocene) and Manchhar groups appear to be completely intermingled, typical representatives of both being interstratified. This shews that the connexion between these two groups is closer than was at first supposed, and further evidence tending to a similar conclusion, and adding greatly to our previous knowledge of the later tertiary *Vertebrata*, has also been derived from the collections of mammalian remains made in the Manchhar beds.

A few mammalian teeth and bones were found by Mr. Fedden in 1875-76 in the beds of the Manchhar group, and, on examination by Mr. Lydekker, were found to comprise some forms found also in the Siwaliks, together with others unknown elsewhere, but having a somewhat older facies. In the course of the

past season a considerable addition has been made to the fossils previously obtained, and amongst other forms teeth of *Sanitherium*, *Anthracotherium*, *Hyopotamus*, *Acerotherium*, and *Amphicyon* have been procured; all have been determined by Mr. Lydekker. Several of these were found by the native assistant, Hira Lal, who accompanied Mr. Blanford; others were obtained from native collectors. The specimens are rare and fragmentary, but sufficient has now been learned of the fauna to shew that it is older than the typical fauna of the Siwaliks, and that it should be classed probably as Miocene.

It has already been mentioned in a previous report that the typical Siwalik fauna has been principally derived from beds in the middle of the group. All the fossils hitherto procured from the Manchhar strata of Sind are from close to the base, from the very beds which pass into the Gáj group, already shewn to be probably of miocene age on independent grounds. We have now found evidence of three later tertiary mammalian faunas in India; (1) that of the lower Manchhar group and of some allied forms elsewhere; (2) the typical Siwalik; and (3) the pleistocene Narbada fauna, other intermediate formations having also been indicated. The Manchhar group has proved to comprise a great thickness of beds, probably not less in places than 8,000 to 10,000 feet; only a few fragments of bones have been found in the higher portions of the group, which may very probably represent the fossiliferous Siwalik rocks.

The march to Sonmiani was undertaken in the hope of tracing a connexion between the Manchhar beds and the highly fossiliferous rocks of late tertiary age on the coast of Makrán, but unfortunately the break between the beds of Sind and those of Makrán appears to be greater than was supposed, the only formations seen between Cape Monze and Sonmiani consisting either of rocks certainly not of later date than eocene, or else of subrecent and alluvial deposits, whilst no appearance of the Makrán beds could be detected except at a considerable distance west of Sonmiani.

Mr. Fedden has done a very good season's work, and has made a large and valuable collection of organic remains in the present and preceding years. He has now been sent to Kattywar to commence the survey of that province, his knowledge gained of the rocks in Cutch and Sind being a great advantage in studying the formations of the neighbouring peninsula of Guzerat. Since his return from privilege leave Mr. Fedden has been most usefully engaged at headquarters in making a preliminary arrangement of the extensive series of fossils from Sind.

One of the native assistants attached to the Survey in 1874 was sent with Mr. Blanford and another with Mr. Fedden, principally as fossil collectors. The former, Hira Lal, although requiring much additional training, proved useful and shewed great willingness; but the assistant who accompanied Mr. Fedden, Ram Sing, was found to be of very little service, and as there appeared no prospect of his ever giving any assistance of value, it was recommended that his probationary service should terminate. He has since, by order of Government, been removed from the Survey.

Mr. Blanford, since his return from the field in March, has been engaged in office work, and especially on the preparation of the geological manual.

During the past field-season none of the officers of the Survey were absent on sick leave or furlough; and still, compared with some seasons gone by, our muster-roll was short, sanction not being yet obtainable to fill the last three vacancies. In view of the work remaining to be accomplished, especially in the geology of the Himalayas, for which arduous work a man must be in full physical vigour, this temporary suspension of our powers is much to be deplored.

Publications.—It is pretty generally understood that in mixed publications of acknowledged authorship the writers are separately responsible for the opinions expressed, the editor's veto being reserved for open breaches of logic or of propriety. As, however, I have been supposed to hold certain views, because they were allowed to appear in the Records of the Survey, it would seem to be the opinion of some that an official body of workers should run in a groove, that the chief of the staff should consider himself so superior to his official subordinates as to form, or at least control, their opinion. The notion may be a relic of the early British idea that a geological survey might be mainly carried on by men devoid of mental culture or scientific training, the materials so collected being worked into shape by a responsible head. In a civilised country, where the main lines of the work are already laid down, and where it is always easy to visit and study any crucial features of the ground, such a system might, to some extent, be practicable; but the attempt would be impossible in India, where, off the main highways, one can only move about with all the incumbrances of a camp; so that the work of inspection would take nearly as much time as the preliminary survey. But, indeed, there is no cause to regret the absence of a system based upon an essentially narrow idea of geological work, in which the important duty of making and recording observations of obscure facts is entrusted to men who can have but a feeble conception of what they are about, and who are without the sure incentive of responsibility for the finished work.

No doubt, however, a chief of the staff is in a peculiar position as editor of a departmental publication, but it seems to me that the rationale of the position tends in our case to loosen rather than to tighten the bonds of his responsibility. As official head of a body of scientific workers, his functions are rather those of the heads of the intelligence and commissariat departments than of the commanding officer. Unless under very unfortunate circumstances, he would certainly have colleagues as competent as himself to do work, and to whom any dictation on his part would be impertinence. In so complex a business as a geological survey, there must be several experts more proficient in their several branches than any one can be in them all, and whose work can only be fully criticised by their peers. Thus, then, the business of the department being to collect and publish information, which is not obtained by manual operations performed by rule, but must be the result of pure intelligence, every member has more or less of a right, according to his ability to produce finished work, to appear as author of that work. And so, under anything like normal conditions, the editorial responsibilities become distributed; and so far, too, it becomes unreasonable to charge the Survey collectively, or its official head, with views that may be taken by one of its members. In many matters, uniformity

must, of course, be insisted on; but some freedom of speculation is necessary to the individual life.

Several considerations of expediency support these principles of right. It would be absurd to accept and publish a man's description of objects or phenomena and not allow him to expose his reasoning thereon. The elements of observation in geological researches are not simple, or to any extent quantitative; they can only be fairly exhibited when put together in argument; and this test is also needed to discover the bias of the observer's mind, the colour of his spectacles, and hence the value even of his plain record of facts. No less may this public exposure be needful to bring the observer to his senses. Ignorance or conceit that would be quite unmoved by individual opinion, may stand corrected before a competent public opinion; and the want of a critical public in India is perhaps the most serious obstacle to our progress. In the absence of local censors we must seek for them abroad, or even permit some mutual criticism in our own ranks. Unfortunately error itself, as presented by a man of any professional education, is often under the protection of the majority; but in this case, too, exposure is the only remedy. On the other hand, coercion and suppression are fatal to human energy of any kind, especially to the development of thought; and mutual encouragement to thought should be the ruling relation in a body of colleagues united in the bonds of a common study.

These considerations are not intended to cover any shirking of the great responsibility that undoubtedly attaches to my post, but only to meet certain false views of what these duties are. There are very special dangers and difficulties in the course I would take; notably the encouragement offered to impostors by facility of publication. Men who have nothing to say worth listening to are often the most anxious to come forward; they would fain measure their own worth by the number of papers or the amount of print having their name attached,—floods of inane descriptive matter without a suggestion of meaning (as if any man could extract positive knowledge from the observations of quacks), or else one-sided pictures from the point of view of some foregone conclusion. We must only recollect that there can be no wheat without chaff and straw, and that the human mind is not an annual that flowers only once, but a strong plant that can bear much pruning and grafting.

The foregoing remarks will explain how the RECORDS of the Survey for the past year have swelled to unusual proportions, but I trust that, on the whole, the change has been to the advantage of our public and ourselves.

I have to apologise for the non-fulfilment of a promise made in the last annual report. Inexperience of large undertakings and a too sanguine temperament led me to hope that the Map and Manual of the Geology of India could be ready by the middle of the past year, whereas much still remains to be done on both, although, with due regard to other necessary work, no time has been lost in their preparation. We can, I think, with certainty promise it for the middle of the current year.

Volume XIII of the MEMOIRS was issued early in the present year, with coloured maps of two important areas—the Rajmahal hills and the Wardha valley coal-fields.

Volume XIV, containing Mr. Wynne's description of the Salt Range, with numerous plates and illustrations, was fully printed off before the end of the year, but there will be unavoidable delay in its issue on account of the map, which presents an intricate piece of colour-printing, and the lithographic branch of the Surveyor General's Office has been so much engaged upon the geological map of India that the printing of the Salt Range map has been inevitably postponed.

I am glad to announce that all the fossil collections from the Salt Range, below the nummulitic horizon, have been confided for description to Dr. Waagen, who studied the formations on the ground and added largely to the collections. As the Survey has been so unfortunate as to lose Dr. Waagen's permanent services, through his inability to endure the Indian climate, we are most fortunate to have secured his co-operation in this very important work, for which he is so eminently qualified.

Of the *PALÆONTOLOGIA INDICA* three fasciculi were issued before the close of 1877: two (Ser. II, 2 and 3) by Dr. Feistmantel on the flora of the Rajmahal group in the Rajmahal Hills, and near Golapili, in continuation of the work by Dr. Oldham and Professor Morris on the same group of fossils, published in 1862. The third is by Mr. Lydekker, forming the second number of Series X, devoted to the description of the Tertiary Mammalia.

Through the kind services of Dr. Oldham in England, we have obtained descriptions by Sir Philip Egerton and Professor Miall of some interesting vertebrate fossils from the Gondwana deposits of Kota-Maléri. The printed sheets and plates of this work were received in Calcutta before the close of the year and have since been issued, with a supplementary note by Mr. Blanford on the stratigraphy and homotaxis of these deposits.

Two other fasciculi of the *Palæontologia* were finally passed for press before the close of the year and are now ready for issue: one (Ser. XI, 2) by Dr. Feistmantel on the Flora of the Jabalpur group; and one (Ser. X, 3) by Mr. Lydekker on some Siwalik Mammalia.

Library.—During the year 1877 the library of the Geological Survey has received an addition of 1,355 volumes; 784 by purchase and 571 by presentation or in exchange.

For the last three months the library-room has been in great disorder during the construction of a gallery and additional cases. As soon as this work is completed and the books arranged, the whole will be carefully checked and compared with the manuscript catalogue, which will then be printed.

Museum.—Much progress has been made in bringing the Museum into order. In December the new wall-cases in the main palæontological gallery were finished; and they are now completely filled with our standard series of fossils in biological succession, though of course at present only in rough generic order. The final arrangement and labelling of the specimens on the shelves will be a tedious labour. In the gallery for Tertiary Mammalia the wall-cases were also finished in December. Mr. Lydekker has these collections so well in hand that the whole are now in excellent approximate order with suitable labels.

In the mineralogical gallery a new set of table-cases were provided during the past year for the minerals and rocks; and, thanks to Mr. Mallet's industry, our valuable series of mineral types is now laid out in perfect order. A valuable addition to this collection was made during the year by exchange with the Mineral Department of the British Museum.

Mr. Mallet has also made much progress with the classification of our collections of economic minerals, both Indian and foreign. This is a branch of our work to which I hope to direct more attention than it has hitherto been possible to do for want of space.

Series of rock specimens, both Indian and foreign, have also been laid out. In the Indian series we must for long be content with much apparent disorder, or at least temporary grouping and labelling, for it represents the current state and progress of the geology of India, which is far from having approached completion. The collection is not even up to date, for hitherto it has been necessary to discourage the collection of rock and mineral specimens for want of place to keep them in.

The geological galleries of the Museum have been open to the public since the 1st January of this year.

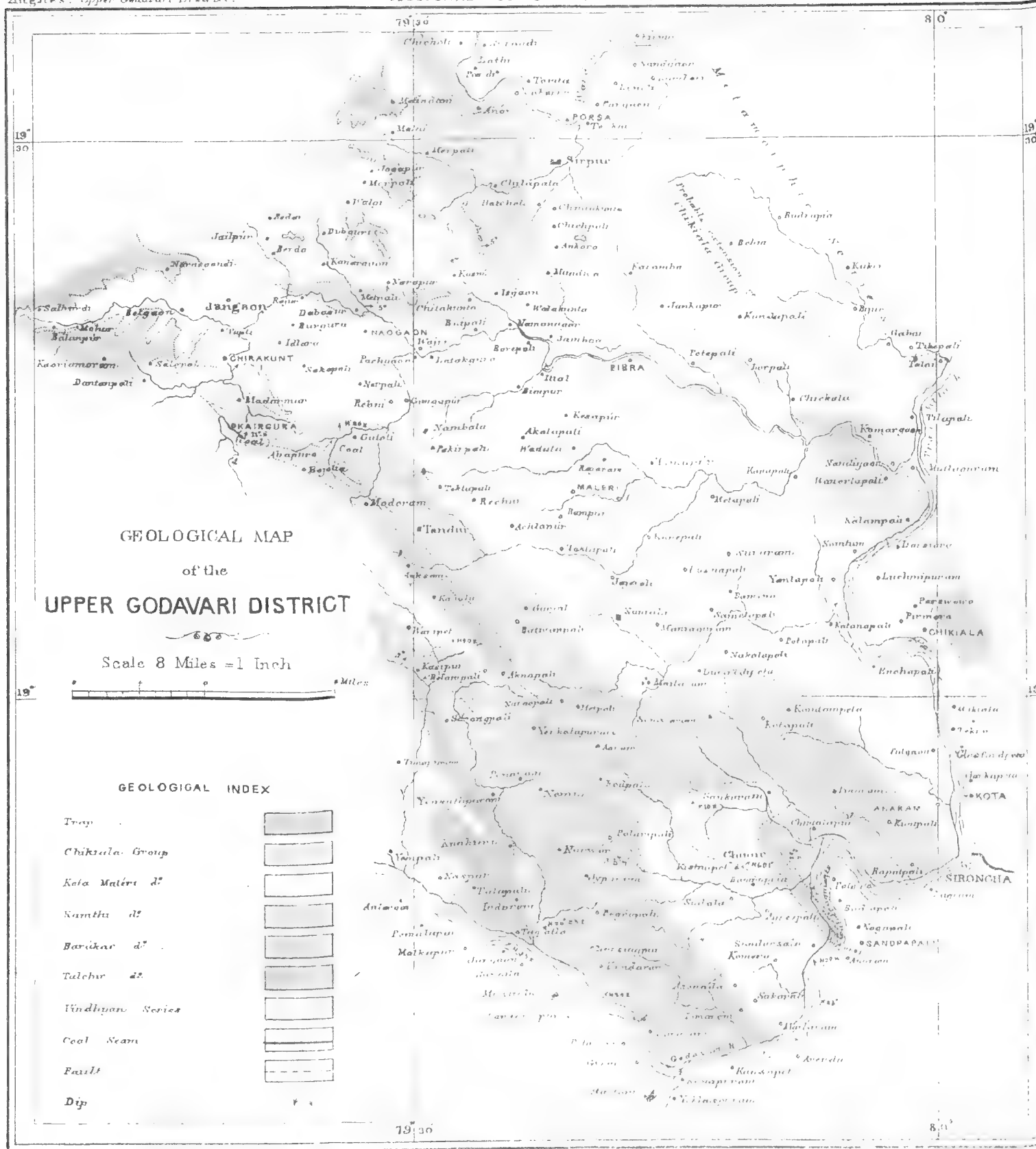
H. B. MEDLICOTT,
Supdt. of Geological Survey of India.

CALCUTTA,
January 1878.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1877.

- AMSTERDAM.—Royal Society of Batavia.
- BELFAST.—Natural History and Philosophical Society.
- BERLIN.—German Geological Society.
- „ Royal Prussian Academy of Sciences.
- BOMBAY.—Bombay Branch of the Royal Asiatic Society.
- BOSTON.—American Academy of Arts and Sciences.
- „ Boston Society of Natural History.
- „ Museum of Comparative Zoology.
- BRESLAU.—Silesian Society of Natural History.
- BUDAPEST.—Royal Geological Institute of Hungary.
- BUFFALO.—Buffalo Society of Natural Sciences.
- CALCUTTA.—Asiatic Society of Bengal.
- „ Meteorological Survey.
- COPENHAGEN.—Royal Danish Academy.
- DAVENPORT.—Academy of Natural Sciences.
- DRESDEN.—The Isis Society.
- DUBLIN.—Royal Irish Academy.
- EDINBURGH.—Royal Scottish Society of Arts.
- „ Royal Society.
- GENEVA.—Physical and Natural History Society.

- GLASGOW.—Geological Society of Glasgow.
 „ Glasgow University.
 „ Natural History Society.
 „ Philosophical Society of Glasgow.
 LAUSANNE.—Vandois Society of Natural Science.
 LIVERPOOL.—Geological Society of Liverpool.
 „ Literary and Philosophical Society.
 LONDON.—British Museum.
 „ Geological Society of London.
 „ Linnean Society.
 „ Royal Asiatic Society of Great Britain and Ireland.
 „ Royal Geographical Society.
 „ Royal Institution of Great Britain.
 „ Royal Society of London.
 „ Zoological Society of London.
 MADRID.—Geographical Society of Madrid.
 MANCHESTER.—Geological Society.
 „ Library and Philosophical Society.
 MELBOURNE.—Mining Department, Victoria.
 „ Royal Society of Victoria.
 MOSCOW.—Imperial Society of Naturalists.
 MUNICH.—Royal Astronomical Office.
 MUNICH.—Royal Bavarian Academy of Sciences.
 NEUCHÂTEL.—Society of Natural Science.
 NEW HAVEN.—Connecticut Academy.
 „ Editors of the American Journal of Science.
 PARIS.—Geological Society of France.
 „ Mining Department.
 PHILADELPHIA.—Academy of Natural Sciences.
 „ American Philosophical Society.
 „ Franklin Institute.
 PLYMOUTH.—Devonshire Association.
 „ Royal Geological Society of Cornwall.
 ROME.—Geological Commission of Italy.
 „ Royal Academy.
 ROORKEE.—Thomason College of Civil Engineering.
 SALEM. MASS., U. S. A.—American Association for the Advancement of Science.
 „ Essex Institute.
 ST. PETERSBURG.—Imperial Academy of Sciences.
 SYDNEY.—Royal Society of New South Wales.
 TORONTO.—Canadian Institute.
 TURIN.—Royal Academy of Science.
 VIENNA.—Imperial Academy of Sciences.
 „ Imperial Geological Institute.
 WASHINGTON.—Department of Agriculture, U. S. A.
 „ Smithsonian Institute.



WASHINGTON.—United States Coast Survey.

„ United States Geological Exploration of the Fortieth Parallel.

„ United States Geological Survey of the Territories.

WELLINGTON.—Geological Survey of New Zealand.

„ New Zealand Institute.

YOKOHAMA.—German Naturalists' Society.

YORK.—Yorkshire Philosophical Society.

Governments of India, Madras, Bombay, and the Punjab; Chief Commissioners of British Burma, Central Provinces, Assam, and Mysore; Superintendent of the Revenue Surveys; and the Resident, Hyderabad.

Notes on the geology of the upper Godávari basin, between the River Wardha and the Godávari, near the Civil Station of Sironcha, by THEODORE W. H. HUGHES, A.R.S.M., F.G.S., Geological Survey of India.

In the Memoir on the Wardha valley coal-field, an arbitrary line along 19° 30' north latitude was adopted as the southern limit of the field, there being in that direction no definite geological boundary of contrasting rocks within the geographical confines of the Wardha valley. The same series and groups, in fact, stretch continuously to the south-east beyond the Wardha field, down the adjoining valley of the Pránhita and that of the Godávari, for more than 230 miles, thus making one great geological region, embracing a large portion of the drainage area of three distinct and important rivers. This region, which, towards the north, has mainly been surveyed by Mr. Fedden and myself, has, towards the south, been under Mr. King's care. We have now brought our leading geological lines from each side to the Godávari river, and there only remains the work of investigating the slight difference that must necessarily have arisen when observers start from widely separated points. This duty Mr. King undertakes next season.

My most recent field notes refer to the district between the Wardha valley and the Godávari (from Naspúr to Sironcha), an area that has up to this time been only cursorily examined.

I was able to distinguish in descending order the—

Trap series—	
Chikiala	group
Kota-Maleri	„
Kánthi	„
Barákar	„
Tálchir	„
Vindhyán series.	
Metamorphic series.	

} Gondwána system.

A.—METAMORPHIC AND VINDHYAN SERIES.

The rocks of the metamorphic series were found always exterior to the Gondwána area. With one exception this is also the case with the Vindhyan:

from Metindáni, in the north-west, to Berda they are the fringing rocks; again, from Kaingúra to Naspúr, and from Mútlágúram, on the Pránhita, to the neighbourhood of Bijór. Near Chinúr, however, there is an inlier of Vindhyan of several square miles in extent.

On the east and the north sides of this inlier, the Gondwánas appear to rest naturally on the Vindhyan; but on the west face the former are, I think, faulted against the latter, as no group of older age than the Kota-Maleri is seen in that direction, whereas, on the Chinúr side of the inlier, Tálchirs occur, and at the same surface level. The alternative supposition that the contact of the Kota-Maleris and the Vindhyan is an original one—all the older groups of the Gondwánas having thinned out—is highly improbable in face of this fact of similarity of surface level; and there seems to me to be further proof of the fault in the Godávári itself, where the Kota-Maleris are in contact with the boulder bed of the Tálchir group,—high and reverse dips being visible.

It was impossible to trace the fault in a north-west direction beyond the vicinity of the inlier, but on the map I have indicated a probable course.

B.—GONDWANA SYSTEM.

I.—Tálchir Group.

This, the lowest group of the Gondwána system, occupies a long belt of ground along the western border of the Gondwána area; a small strip near Chinúr; and a few little patches elsewhere.

Its characteristic features are well seen in many sections, but the needle shales, instead of being the most prominent rocks, are quite subordinate to the sandstones. It was rare indeed to meet with any of the former. The boulder bed, however, is strongly developed, and in some places is the only representative of the group. This is so in the case of the little patch of Tálchirs near the boundary of the Vindhyan north of Naogaon. The boulder bed is conspicuously exposed in the vicinity of Mádorám, and near Tándúr; and more or less continuously from Kásipúr to Naspúr. In the Godávári river, it is seen on the right bank near Sandrápali. Many of the boulders are of gneiss and of enormous size, but the generality are small, and consist mainly of Vindhyan shales, limestones, and sandstones.

It is easy to trace the extension of the Tálchirs northwards in the direction of Chinúr by means of the boulders strewn on the surface; many of the blocks being of gneissose and granitic composition. Such, when met with, may, I think, unhesitatingly be accepted as signs of the Tálchir formation. Tálchir group, not a single instance of their occurrence in any of the other groups of the Gondwána system having ever come within the range of my experience. The doubts that assailed me as to the true horizon of the boulder bed when I first noticed it near Sandrápali were dispelled so soon as I discovered gneiss and granite boulders.

The boundaries of the Tálchir group are almost everywhere those of original contact; but in the neighbourhood of Kásipúr, and between that village and Aknápali, there are several faults. The most distinct of them is the one that I

have indicated as being probably the continuation of the fault along the west face of the Vindhyan inlier near Chinúr. It is very plainly seen a few yards below the junction of a small stream with the river shown on the map as flowing from the direction of Batwanpali towards Kásipúr. The dip of the Tálchirs is in contrast with that of the Vindhyan, the latter varying between 20° to 40° east of north, that of the former being north-westerly.

I have not been able to trace, as closely as I could have desired, the limits of the Tálchirs between Sárangpali and Naspúr. Amongst the causes that prevented me from so doing, the most trying difficulty to encounter was the real or pretended incompetency of the guides. They could direct me from their own village to the next one so long as I kept on the main road, but if I ventured to strike into the jungle, troubles at once commenced, a cloud of incomprehension settled on them, and to every question regarding distances, relative positions of rivers, hills and villages, I received one constant answer "*Yerki ledu*," "don't know." It may be that the tendency of the people (Gonds and Kolams) to change their place of habitation at short intervals, prevents them from becoming acquainted with more than a circumscribed area around their temporary houses, but on many occasions I suspected that ignorance was affected in order to avoid possible compulsory service of unknown duration.

In addition to the infliction of unqualified or unwilling guides, supplies were difficult to procure, villages being small and far apart, and a more than usually large number being deserted¹ owing to the want of water, there having been a failure of rain in the monsoon.

The map was a most unreliable source of reference in many instances. For

Map unreliable near Sárangpali. . . example, near Sárangpali, the large river west of

the village is shown as being distant about a mile, whereas in reality it is nearly three miles away. And the river east of Sárangpali, instead of rising in the neighbourhood of Yenkatápúram, takes its origin near Sárangpali. The error in placing the large river west of Sárangpali so close to the village, has thrown my boundary line entirely out, and I have had to reduce the real breadth of the Tálchir exposure by at least three-quarters of a mile.

I failed to discover any organic remains, although I occasionally made very diligent search in places where I hoped success might reward my labours. That the Tálchirs contain several plant forms has been demonstrated by Dr. Feistmantel, and I was extremely anxious to collect a few specimens from the upper Godávari area, in order to compare them with the flora of our Bengal fields.

II.—*Barákar Group.*

The lithological features of this group are quite as characteristic here as in the Wardha valley, and there is no difficulty in recognising the formation where there is a fair exposure of it. But the drawback to identifying it, and tracing its boundaries, is the fact of the very incomplete sections that one has the opportunity of examining. It will be seen by looking at the map that no Barákars are shown

¹ It is the wont of the Gonds and Kóláms to leave their homes in the warm season for service with the proprietors of villages whose lands are more fertile and better cultivated than their own.

overlying the Tálchirs between Kásipúr and Tétmatla on the left bank of the Godávari. Now, I am by no means prepared to assert that Barákars do not occur exposed at the surface, but in the absence of a single section to which I can refer as yielding undoubted evidence of the presence of Barákar strata, I have preferred to suppress the probable boundary lines which it would have been easy for me to indicate. The more so also, as perhaps an erroneous impression might have been conveyed respecting the possible existence of coal.

Actual coal outcrops occur only in a few places. There are none in the small patch of Barákars overlying the Tálchirs north of Naogaon. But in the belt of rocks extending from Kairgúra to Tándúr and onward, there are several exposures of coal.

The most northerly of these is one near Kairgúra. The seam is seen in the right bank of the river that flows past the village of Chirákúnt, a few yards north of the Tiráni road ghát. Only a portion of its total thickness is visible. Descending, the section is :—

Coal	.	.	.	.	.	.	.	3'0"
Carbonaceous shale	.	.	.	.	.	.	.	0'8"
Coal	.	.	.	.	.	.	.	0'7"
Carbonaceous shale and coal	.	.	.	.	.	.	.	...

The dip is a little east of north, at an angle of 15°.

In a small stream, east of the main river and tributary to it, a much clearer section of the seam is exposed, and its entire thickness is 15 feet. Most of it is coal, and much of it of fair quality. The average composition is, according to an assay made by Mr. T. H. Turner, the Assistant Curator of our Museum,—

Volatile matter (moisture 9·4 per cent.)	.	.	.	.	.	42·2
Fixed carbon	.	.	.	.	.	45·6
Ash	.	.	.	.	.	12·2
						100·0

Like the coal of the Wardha valley, and those of the several Godávari fields, there is a large amount of moisture in this sample. The fixed carbon is somewhat deficient, but the proportion of ash compares favorably with the standard for ordinary Barákar coals. Underlying the seam is sandstone identical with that which in the Wardha valley I have described as "nodular sandstone," and which there always occupies a position immediately or almost immediately (argillaceous shale sometimes intervening) under the coal. In the area that I am now describing, this kind of sandstone is constant in such sections as are exposed, and I would accept it as an almost sure sign of coal.

There are no Tálchirs seen below the Barákars, in the river or elsewhere near Kairgúra, the former being overlapped by the latter, which here rest naturally upon the Vindhya.

The next outcrop of coal that I met with was about half-way between Kairgúra and Ábápúr. I look upon it as being the extension of the Kairgúra seam in a south-easterly direction. At the surface it shewed a diminished section, being only 5 feet,

instead of 15 feet thick. It is probable, however, that when sunk into, an increase will be proved. The quality of the coal appears to be the same as that at Kaingúra, and it possesses the same tendency to split, after exposure to the air for a short time.

Another outcrop of this seam may be seen in the branch stream of the Gúloti river coming from Ábápúr. It is, as usual, near the top of the group, and is underlaid by very typical nodular sandstone. There is no other section in which the Barákars are so fairly exposed as in this one; and all the rocks are sufficiently characteristic to render their determination a matter of ease. The total thickness of the seam measurable is 9 feet. The direction of its dip is north 20° east, and angle of inclination 11° .

I met with no other outcrops of coal, except the three mentioned above; but the fact that coal occurs, and is visible at intervals over a length of seven miles of country, makes it highly probable that it is continuous throughout the belt of Barákars from Kaingúra to Aknápalí. To test this point, bore holes may be put down anywhere near the junction of the Kámthis and Barákars, some allowance being made for overlap, for here, as in the Wardha valley, the former creep over the shore edges of the latter.

From Aknápalí to Tétmatla, there are no Barákars shown upon the map. As I have already said, I am not prepared to maintain that they are absent, but I did not come across a single section which satisfied me that the rocks I saw were those of the Barákar group. Near Tétmatla there are sandstones which at first sight are somewhat difficult to discriminate from Barákars. In colour and texture and composition they are undistinguishable, but their method of weathering is different. They have rounded outlines, and they have lost the distinctness of their lines of stratification—a feature not usually observable in the Barákars, but common in the Kámthis. I have accordingly placed them in the latter group.

Although Barákars are not seen, it is quite possible that coal exists, and I would advise sites near Sáránpalí, Yenkatápáram, and Tétmatla as being likely to prove successful in the event of borings for coal being undertaken. In the river east of Tétmatla, about 500 or 600 yards above its junction with the Godávári, there are some very promising Kámthi sandstones, and a hole of 300, or at the most 400 feet, ought to strike coal if it occur.

The only other remaining Barákars in the field that I could recognise occupy a narrow strip of country extending from Chinúr to Sandrápalí. That these rocks are of Barákar age, is testified by their well-marked lithological characters; and in the Godávári the nodular sandstone is a prominent and specific indicator of the group. The thickness of the entire series of beds is under 200 feet. There is no outcrop of coal, but the sandstone immediately under coal occurs at the mouth of the Sandrápalí stream, and a boring in the right bank of the Godávári, a little below the union of the two rivers, will in all likelihood strike coal, within a moderate depth from the surface. I found large fragments of coal in the bed of the Godávári

opposite Pálgúla, and I traced them up to within a mile or so of Sandrápali. This discovery was additional, and very satisfactory, evidence of the existence of coal somewhere in the neighbourhood of Sandrápali, and I have no doubt whatever that the site I have recommended for a bore hole is a spot which, when tested, will justify the anticipations that my observations have given rise to.

Two of the pieces of coal that I picked up, I sent to the Tahsils of Chinúr and Madápúr to be deposited there and shown to such as might be interested in mining matters, and who perchance would pay a visit to Sandrápali on hearing of the likelihood of coal being found in the vicinity.

Measuring as the crow flies, Sandrápali is only six miles from Sironcha, a station that, by the completion of the Godávári navigation scheme, would be brought into communication with the coast line of the Bay of Bengal. In the event of steamers plying up and down the river, it would be a convenient depôt for coal,* with the advantage of being in British and not foreign territory.

Some thirty years ago, hope and rumour pointed to Kota, a fortified village on the left bank of the Pránhita, four miles above Sironcha, as a likely locality for coal. The expectation was never realised, but it is somewhat interesting to know that if efforts had been guided to an almost equal distance from Sironcha, and in a direction opposite to Kota, coal might perhaps have been discovered.

The question of available fuel near Sironcha is not of such moment with reference to the requirements of a railway, supposing the Wardha Valley State line to be pushed on in the direction of Haidarábád. Such extension would probably follow a course that would render the localities at which outcrops have been mentioned, or the spots where borings have been recommended, more convenient centres of supply.

That coal occurs at Sandrápali is, of course, only a supposition, but a supposition that, according to my belief, is very little removed from a certainty, and as a shallow boring or two will suffice to set doubts at rest, I would advise early

Borings at Sandrápali advised.

action in the matter to be taken. With positive knowledge of the existence of coal, instead of a hypothetical basis to go upon, schemes depending upon the accessibility of coal within given limits may probaby be brought to an issue.

To my knowledge there are no Barákars in the valley of the Pránhita, and I was unable to recognise any along the north-east boundary between Mútlágúram and Kirmíri.

III.—Kámthi Group.

In the determination of this group, I have been mainly guided by my experience of it in the Wardha valley coal-field. At the base, we there had a series of sandstones usually coarse-grained, porous and friable, and slightly yellow, reddish-brown or grey in colour; above, more compact sandstones. The character of the sandstones at the base is what I wish to draw attention to, for in several places in the area that I am describing in this paper, I have depended

Porous sandstones, typical upon the porosity of the sandstones for the correct rocks.

ness of my assignment, but, of course, it must be understood only when the sandstones exhibiting this feature were at such an

horizon that the analogy with the Wardha valley might be quoted to justify my having done so.

As specific rocks in the higher portion of the group, I have accepted the compact argillaceous shales and sandstones of deep red, buff and pale purple colours, they being very characteristic, both in the district from which the Kámthis derived their name, and in the Wardha valley.

The mapping of the Kámthis has been beset by the same difficulties, arising from imperfection of sections, &c., as were experienced in the case of the Tálchirs and Barákars. The aspect of the strata composing the Kámthi group being also much more diversified, it was not always that one could vouch so positively for the correctness of one's determinations of isolated rocks as in instances where Tálchirs and Barákars were concerned. There is not the sameness in the Kámthi group, as in the other two, and it was always necessary that one should be prepared to receive as a portion of its series a bed of uncertain aspect.

The lower boundary of the Kámthis may be accepted as fairly accurate throughout, but the upper is open to possible correction. Mr. King and myself differ slightly as to what shall be considered the limit to the Kámthi group. In his paper, contributed to the Records of the Survey (Vol. X, page 55, 1877) he introduces between the Kámthis and the Kota-Maleris, a group consisting principally of sandstones, which he names after the town of Sironcha. I see no necessity for establishing this group. The sandstones from Sandrápali to the junction of the Godávari and the Pránhita at any rate are undoubtedly Kámthis; and sandstones differing in no respect from those opposite Sironcha are to be found above what I imagine to be beds of undisputed Kota-Maleri age. One of the chief reasons for the elevation of the Sironcha sandstones into a separate group was founded upon an erroneous observation which modified a case of oblique lamination into one of unconformity.¹ On re-examination, this season, of the section (which Mr. King and I on the first occasion visited together) where we formerly thought ourselves justified in concluding that there was a slight unconformity in the succession of the beds, I saw reason to change my opinion. Referring the point to Mr. King for his judgment, he, after inspecting the section again, agreed with me. As therefore there is no break, I am inclined to throw the boundary of the Kámthis more to the north and east, thus subtracting a considerable thickness of beds from the Sironcha group. It is quite true, as Mr. King remarks, that opposite Sironcha the sandstones differ in many points from those of the country to the south (and north-west). "They are micaceous, thick and thin-bedded, harsh, even-textured, grey and brown sandstones, but they at the same time contain fragments of buff and pink shales." On lithological grounds I think they are separable from the Kámthis, and so far I agree with Mr. King, but, instead of isolating them, I would place them with the Kota-Maleris.

The leading characteristics of the Kámthis within the limits of my work, correspond with those already set forth in the first place by Mr. Blanford,

¹ Records, Geological Survey of India, 1877, Vol. X, Part II, page 61.

and in the second place by myself.¹ It seems to me unnecessary therefore to repeat them in a special paragraph, the purpose of this paper being satisfied if I allude to them incidentally while describing the distribution of the group.

The most northerly rocks are those which form the extension southward of the Kámthi area, the description of which in the Memoir of the Wardha valley ended at the arbitrary boundary of 19° 30' north latitude.

The bottom coarse-grained, porous and friable sandstones are very well exposed in the river flowing past Mérpali in the direction of Sirpúr, and along the west boundary generally they are clearly seen. They rest upon Vindhya as far south as Chitakúnta.

The upper rocks, consisting of fine-grained, compact sandstones; granular, brown, ferruginous sandstones; and coarse, white and grey, felspathic sandstones, constitute high land north and south of the Mérpali river. They are gradually overlapped by the Kota-Maleris as they extend southward, and where the boundary turns to the west, there is a great decrease in the thickness exposed. A moderately fair section of the Kámthis is seen in the Jangaon river, and near Dabágúr there is a thin bed of slightly carbonaceous shale. It is so very rare to meet with anything at all approaching carbonaceous shale in the Kámthis, that I notice its occurrence in the present instance as being an unusual circumstance. Above Dabágúr, towards Rájúr, there are some red clays associated with the sandstones, and this gives some ground for suggesting that the determination of these as Kámthis is incorrect; and that they ought to be placed amongst the Kota-Maleris. Red clays are certainly very common amongst the Kota-Maleris, and especially so in the Jangaon valley, but the sandstones with which the red clays in question occur, are not of the Kota-Maleri type, but resemble closely some of the sandstones of the lower series of the Kámthis. South of the Jangaon river the Kámthis appear in their greatest force and stretch for 50 continuous miles from Chiráakúnt to the banks of the Godávari. All the different varieties of sandstones that the group possesses are represented: the compact grits breaking with a conchoidal fracture, the blotchy sandstones, the ferruginous sandstones, the porous sandstones, &c., &c. The middle and the upper sandstones form a good deal of high land. Towards the base of the principal range of hills extending from Némúr to Kansápet compact argillaceous sandstones occur. These are very characteristic rocks of the Kámthi group, but they are by no means of such frequent occurrence in the Godávari area as they are a hundred miles further to the north.

Looking at the map, it will be seen that in the Godávari river above Sandrápali, I have marked the upper limit of the Kámthi group as being near Arénda. By this assignment, the rocks that Mr. King distinguished as Táchérila sandstones (from a village 12 miles to south-south-west of Arénda) are brought within the embrace of the Kámthi area. I believe the evidence as to the true position of these Táchérila sandstones further to the south is somewhat obscure, it being possible indeed to infer that they are lower in the series than the Kámthis. Unless the rendering of the Godávari section, however, has been

¹ Memoirs, Geological Survey of India, Vols. IX and XIII.

complicated by faulting that I have overlooked, the Táchéría sandstones are, I think, more properly placed with the Kámthis than below them.

Rocks that I consider to be Kámthis occur east of Chinúr, and overlie the Kámthi group near Chinúr. Barákars at Sandrápali. The porous type sandstones are exceptionally well developed near Chin-tálapúr, where they form a low ridge striking north-west and south-east. The more compact varieties are best seen in the direction of Kotapali. The upper boundary as marked by me, near Sironcha, is open to question, for the reason already pointed out, that Mr. King is inclined to introduce a group between the Kámthis and the Kota-Maleris. To the introduction of this group I am somewhat opposed, the grounds for the separation being to my mind insufficient.

IV.—Kota-Maleri Group.

Overlying the Kámthi group are the Kota-Maleri beds, made up largely at the base of red and green clays; fine-grained, speckly-grey sandstones; open mottled purple or red and white sandstones; thick-bedded white sandstones, with coarse gravel scattered through it in parts or occurring in ill-defined runs; soft and somewhat unctuous sandstones of various colours; and pisolitic argillaceous sandstones and grits: most of these lower sandstones contain clay galls. The clays, and more especially the red ones, are the most conspicuous beds of the group, and at the same time form a very striking feature in the surface aspect of the country. Over considerable areas, nothing but red soil is to be seen, and for many miles between Bibra and Nakalápalí, on the high road to Sironcha from Chándá, this is the predominant colour.

The clays are by no means constant in thickness, their most profuse development being in the west and the north-west division of the map. In the section exposed by the Pránhita, the proportion they bear to the other rocks of the group is small.

Clays are not so abundant high up in the series as at the lower horizons.

The dip of the Kota-Maleri group is in conformity with that of the underlying series both in the Godávari and Pránhita sections, but the unconformity of overlap becomes evident when the lower boundary is followed for some distance. In the Memoir on the Wardha valley, I pointed out that this was the case, and the testimony is repeated here.

Associated with the clays are the limestones at Kota, from which the fish *Lepidotus* and *Dapedius* were obtained. At Kota the limestones, like the clays, are not of conspicuous thickness; but, like the latter, they become much more prominent members of the series towards the north-west; and near Bimpúr and Itial, 36 miles from Kota, they form a well-marked, though low hill range. That the limestones so abundantly developed in the north, and there attaining a thickness of over 100 feet at the least computation, are the continuation of the few feet seen at Kota, is, I think, a point fairly established by the likeness that the rocks bear to each other, and by the discovery of fish scales at Itial similar to those found at Kota.

I was not able to trace them much beyond the vicinity of Itial, but in the other direction, and the further side of Kota, Mr. King succeeded in picking them up in the Godávari.

With reference to the clays at Maleri, in which were obtained teeth of the fish *Ceratodus*, and remains of the reptiles *Parasuchus* and *Hyperodapedon*, the Itial limestones, and consequently the Kota limestones are higher in the series. To this circumstance I attach no stronger significance than that of local super-position, for clays and sandstones similar to those below the limestones occur above them, and the evidence appears to me insufficient to justify the separation of the red clays and sandstones of Maleri from the red clays and sandstones above the Kota limestones. The circumstance, that hitherto none of the Kota fish have been found at Maleri and none of the Maleri forms at Kota, may be said to be suggestive of separation; and as the relative position, in which the organic remains occur, is in accord with the experience of European research (*Parasuchus*, &c., occurring in older strata than *Lepidodus*, &c.), there is an additional reason for suspecting a break in the deposition of the Kota-Maleri group. Considering, however, how limited have been our efforts in search of organic remains, it is premature to give much force to the negative evidence that lies before us on this point; and I cannot see how European analogy affects in a decisive manner the grouping of beds in India that are identical in composition and appearance, and amongst which no unconformity in its strict meaning occurs. It may be that the component strata of the Kota-Maleri group, being fluviatile formations, there was changing distribution of deposits, giving rise to irregular beds,—as, for instance, the very clays and limestones that we have been alluding to; but this is quite in accord with the known character of deposits formed under the conditions supposed to have then existed in the Kota-Maleri area, and is no proof of unconformity.

In the Maleri clays, the fossil remains most commonly found are those of *Hyperodapedon* and *Parasuchus*. I have succeeded in extending the area of their occurrence over a large portion of the Kota-Maleri country. One of the localities where they are found is Agrézpali, 4 miles south and a little west of Chinúr, in clays which are high in the series, and presumably much higher than the Kota limestone horizon. But on this point I cannot insist, as owing either to the imperfection of the sections in the Godáviri and its valley, or to the absence of the limestone band in this direction, I failed to get direct evidence of the position of the clays relative to the limestone.

Though this failure is to be regretted, the probability is suggested that amongst the clays above the Kota limestone similar reptilian remains to those met with in the Maleri clays may be found. Should this likelihood be converted into reality, the objection that may be founded upon the present evidence and European analogy to the incorporation of the clays, &c., above and below the Kota limestones in one group would be removed.

The higher portion of the Kota-Maleri group is not so characterised by clays as the lower. It is chiefly made up of sandstones, the most typical of which are coarse and loosely compacted sandstones of various colours, with broken runs of buff and pink shale fragments through them, rusty-brown and grey sandstones containing pebbles, and yellowish-grey sandstones, varying in texture, with dark stains of peroxide of iron, and sub-angular pieces of yellow opaque quartz scattered through the rock.

Sandstones containing shale fragments are found at various horizons, but they are of most common occurrence above the main body of clays. They are met with in full force, forming high land, east of Bibra. I have not determined the boundary in this direction.

The flora of the Kota-Maleri group, as it at present stands, is represented by only a few species of plants discovered at the following localities :—

Flora.

From Anáram, opposite to Kota—

Palissya conferta.

Cheirolepis Muensteri.

From Naogaon, in the valley of the Jangaon river, and 9 miles east of Jangaon village—

Palissya Jabalpurensis.

Araucarites Kachensis.

From between Móhár and Balánpúr, 12 miles west of Jangaon village—

Palissya conferta.

Cheirolepis Muensteri.

From Chiráakúnt, 4 miles south of Jangaon—

Teniopteris, sp.

Ptilophyllum acutifolium.

Cycadites, sp.

Palissya, comp. *conferta*.

Palissya, sp.

Of the fossils from Chiráakúnt, which were obtained during the early part of this year (1877) and have only been recently examined by Dr. Feistmantel, he says—

“The fossils from Chiráakúnt, as far as I can determine or correlate them at present, are—

FILICES.

“*Angiopteridium* (*Teniopteris*) sp. About 3 leaflets of a very slender form, with well-marked midrib, and thickish, dichotomous secondary veins, passing almost horizontally out of the midrib. The same form is as yet only known in the Ragavapuram shales, and reminds one of *Teniopteris Daintreei*, McCoy, from mesozoic rocks in Victoria and Queensland, which is an *Angiopteridium* also.

CYCADEACEÆ.

“*Ptilophyllum acutifolium*, Morr., the common form.

“*Cycadites*, sp.—a leaflet belongs to this genus and is of the Ragavapuram type.

CONIFERÆ.

“*Palissya* comp. *conferta*.—There are pretty numerous branches of a conifer, which, I think, belongs to this type of the Rájmahál group, and Sripermatúr group (= Ragavapuram beds).

“*Palissya* sp., a different species.”

Associated with these plants, I found some casts of a bivalve shell, resembling an *Unio*. Dr. Feistmantel was unable to determine it.

By reference to Mr. King's table of strata (Rec. G. S. I., Vol. X, part 2, page 56), it will be seen that the Ragavapuram shales, which overlie the Rájmahál group (Golapili sandstones) near Golapili on the lower Godávári, are placed as the equivalents of the Kota-Maleri group. That the beds in which the Chirákúnt fossils occur do belong to the Kóta-Maleri group is a point in regard to which I myself have no doubt. In the neighbourhood of Idlára there are the unmistakable red clays with lenticular layers of greyish-green granular argillaceous sandstones,¹ and sandstones with clay galls, of the Kota-Maleri group. Thence to the south, as far as the range of hills capped by trap, there is no interruption to the series; and, at a short distance up the north face of the range and about a mile and a half east of Chirákúnt, soft, pale yellow, fossiliferous shales occur that yielded the few species of ferns, cycads, and conifers, &c., which were enumerated above.

Dr. Feistmantel's conclusion as to the age denoted by the flora bears out the determination made by myself in the field.

Amongst the plants at Chirákúnt there is one conifer, *Palissya conferta*, which occurs at Anárum in sandstone under the Kota limestone bed. Hitherto it has been considered a very characteristic form of the Rájmahál series,² but if the Chirákúnt beds are the equivalents of the Ragavapuram shales, and the Ragavapuram shales are younger in age than the Golapili sandstones or Rájmahál group, the vertical range of *Palissya conferta* is increased. If, on the other hand, its restriction to the Rájmahál group be maintained, then an alteration in the classification of the rocks must be made. The more reasonable view, however, is, I presume, to admit the wider range of *Palissya conferta*.

The same plant was discovered in 1872 by Mr. Fedden, between Móhár and Balánpúr, west of Jangaon, in sandstones which I have included as Kota-Maleris. These sandstones (that is, those in which plants occur) are very like in appearance to the Golapili sandstones, in which *Palissya* is found. Mr. Fedden, speaking of these Balánpúr beds, says, "They consist of fine softish sandstones, in parts silty, and with ferruginous bands and layers, the latter having plant-like flutings and hollow, wood-like casts, so characteristic of some of the upper jurassic beds of Kach. Moreover, some of the ferruginous bands have septaria-like intersections. The few specimens of *Palissya* and isolated leaflets that were found occurred in the finer silty sandstone." Mr. Fedden, it may be noticed, alludes to an upper jurassic likeness; and more than once in his manuscript report for the season 1871-72, when describing different portions of the geology of the Jangaon river valley west of the town, he adverts to the circumstance. Whether these Móhár-Balánpúr *Palissya* beds are like the Golapili sandstones, or like the upper jurassic rocks of Kach, there is no doubt that they constitute a part of the Kota-Maleri group.

The shales and sandstones near Naogaon (in which I last year discovered *Palissya Jabalpurensis* and *Araucarites Kachensis*) are also components of the

¹ These are very characteristic beds of the Kota-Maleri group.

² See Palæontologia Indica, 1877, Ser. II, 3, Jurassic (Liassic) flora of the Rájmahál group from Golapili (near Ellore), South Godávári District, p. 183.

group. They may be higher in the series than the Móhár-Balánpúr beds, their plant forms suggesting this surmise. I cannot adduce any stratigraphical evidence that bears upon the relationship of the Naogaon and Móhár-Balánpúr or Chirá-kúnt beds, for sections are of the most broken and uninformative character throughout the whole of the valley of the Jangaon river. The rocks that appear are sufficient indexes of the group, but they are inadequately exposed for nice determinations of stratigraphical questions. A look at the map will tell rapidly and clearly the extent of area that I include under the head of Kota-Maleris. The names of localities invested with most interest are printed in block type, and it is easy to note their relative geographical positions. The conclusions regarding the Kota-Maleri group and their distribution are—

- 1.—That they overlap the Kámthis, but are not directly unconformable to them.
- 2.—That the red clays and sandstones of Maleri, and the red clays and sandstones above the limestones of Kota, are conformable members of the same group, undistinguishable lithologically, and presumably containing like reptilian remains.
- 3.—That the Kota fish beds, and the Maleri fish and reptilian beds, belong to the same group.
- 4.—That the plants of Rájmahál type in the Anáram sandstones (*Palissya conferta* and *Cheirolepis Munsteri*) and the plants from the Chirá-kúnt shales, are from the same rock group.
- 5.—That the affinities of the plants are with the upper Gondwána, rather than with the lower Gondwána flora.

V.—*Chikiála Group.*

On the left side of the Pránhita, there is a range of hills near Chikiála, which attracted the attention of Mr. King and myself when encamped at Énchápali, as it was apparent that they were made up of thick sandstones, differing from those constituting the Kota-Maleri group. On examination, we found the scarp that we ascended made up of heavy conglomerates with a large percentage of ferruginous matter, ferruginous glassy-looking sandstones, and soft sandstones with thin iron bands. The general colour is brown, as might have been anticipated from the fact of so much iron entering into the composition of the rocks. The conglomerates contain many fair-sized pebbles 3" or 4" to 6" long. Some of the sandstones present a mammillated weathered surface, a feature that reminded Mr. King forcibly—when taken in connection with their lithological character—of the rocks which in the lower course of the Godávari he has classed as upper jurassic (Tripetty group).

The Chikiála rocks extend across the Pránhita in a north-west direction, and I traced them as far as the river that flows near Bibra. Throughout there is a strong development of ferruginous matter, either in the form of bands of varying thickness or in concretionary masses, or as scattered colouring substance. Fragments of foreign rock in the sandstones are also common. The iron ore worked by the smelters of the country is derived almost entirely from the Chikiála group.

The main development of the Chikiála group is in the Pránhita region; but overlying the Kota-Maleris near Balánpúr is a small thickness of rocks that I would include as members of the Chikiála series. The discovery of coal of jurassic habit is the chief element of distinction; otherwise, I should scarcely have felt warranted in limiting the Kota-Maleri upper boundary at any bed but that in contact with the intertrappeans or trap. The coal occurs in irregular strings, in a clay shale, of which 5 feet are exposed. Above, is yellow, soft sandstone, obliquely laminated at the top, and containing fragmentary carbonaceous markings. The upward section for a short distance is obscured, and then intertrappean and trap beds follow.

It is only in this one locality that I have ventured to map beds of a higher horizon than Kota-Maleris beyond the limit of the Pránhita valley, but in two instances, along the southern side of the Jangaon river valley between Chirákúnt and Belgaon, I noticed a sandstone with ferruginous concretions that would have passed muster as a Chikiála sandstone. I am simply following Mr. King's lead in placing the rocks at Chikiála as a group distinct from the Kota-Maleris.

NOTES ON THE GEOLOGY OF KASHMIR, KISHTWAR AND PANGI, *by* R. LYDEKKER, B.A.,
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INTRODUCTION.

DURING the past summer I have been engaged in examining the rocks of a considerable portion of Kashmir, and of the valley of the upper Chináb, as far as British Lahúl. A great portion of the area traversed has been entirely new ground in a geological point of view; while other parts have been those which remained between the various lines of section taken by the late Dr. Stoliczka, and by the survey of which these various lines have been brought into connection with one another.

Although I have been able to color in a considerable portion of the map, yet the results obtained from the season's work are not in every instance quite so exact as I could have wished, owing to the fact that almost all the strata described, with the marked exception of the carboniferous series, are unfossiliferous. This absence of organic remains compels us, in referring the different rock-groups to their proper geological horizons, to depend on purely stratigraphical evidence; and in some cases this kind of evidence is but uncertain. It must, therefore, be clearly understood that probability plays a certain part in the correlation of some of the disconnected rock-groups.

It may, perhaps, here not be out of place to call attention to the extraordinary absence of fossil remains in so many of the Himalayan formations. This absence is equally noticeable in the silurian slates of the Pír Panjal and Kashmir, in the equivalent slates and limestones of Pangí, and in the older Tertiary deposits of the outer hills. In the still older gneissoid and micaceous rocks, traces of fossils might have been expected to have been, to a great extent, obliterated by subsequent metamorphic action; but even among these older metamorphic rocks there are

many beds of comparatively little altered slates and shales which ought to have retained traces of organic life had such lived in the seas in which these rocks were deposited. I think that we cannot but conclude from the absence of fossils in so many deposits, so favorable to their preservation as are the limestones of the Kiol and Krol groups, that parts of the old Himalayan seas, strange as the fact may appear, were from some yet unknown cause, over wide areas unfavorable to any great developement of animal life.

As the country traversed by me consists of several semi-distinct lines, I have thought it best to treat of these several lines or sections under distinct headings, following in this respect the example set by the late Dr. Stoliczka in his memoir entitled "Geological Observations in Western Tibet."¹ This method has many obvious advantages, although it is open to the objection of necessarily involving a certain amount of repetition.

The survey of a wider area has necessarily led to certain modifications of some of the views expressed in my previous paper on the "Geology of the Pír Panjal;" in the main, however, the conclusions there arrived at as to the ages of the different rock-groups have been maintained.

I have here to offer my thanks to Mr. Drew, late of the service of the Maharajah of Kashmir, for the gift of notes and sections taken by him in various parts of Kashmir territory, and which have afforded me several important pieces of information, as well as suggestions in classifying the different rock-groups.

I.—THE TERTIARIES AND POST-TERTIARIES OF KASHMIR.

The so-called Karewahs of Kashmir have already been treated of by several writers, among the best known of whom are General Cunningham in his "Ladak;" Major Godwin-Austen in the "Quarterly Journal of the Geological Society of London;"² and Mr. Drew in his "Jummoo and Kashmir Territories."³

During the early part of last spring I proceeded along the Kashmir side of the Pír Panjal range, for the purpose of tracing the boundaries of these deposits.

Along the greater part of the north side of the Pír Panjal, after leaving the older rock-series, we come upon beds of either clays, sands, gravels, or conglomerates, which have the normal north-westerly strike of the Himalaya, and a north-easterly dip varying from five to twenty degrees. Mr. Drew has noticed the occurrence of these beds at page 211 of his above-quoted work, and I have already referred to their presence at Báramúla in the "Records of the Geological Survey of India."⁴

At Báramúla these Tertiary beds consist of yellowish clays and conglomerates, with an average dip of about ten degrees; the same conglomerates are also developed in great force to the north-east of the latter place, where they are still more tilted, and where they have a very great resemblance to the upper conglomerates of the Siwalik series of the outer hills. The blue clays and yellow

¹ Mem., G. S. I., Vol. V, p. 337.

³ Pp. 207, 166.

² Vol. XX, p. 383.

⁴ Vol. IX, p. 162.

sands can be traced to the north as far as Shalúra. To the south-east of Bámúla, almost up to the town of Shapiyan, the lowest beds of these deposits consist of stiff blue clay, with the same dip and strike, the conglomerate beds being generally either absent or replaced by clay; the conglomerates, however, reappear at Hirpúr on the Pír Panjal road. Major Godwin-Austen has noticed that these conglomerates and sand beds at the latter place are several hundred feet in thickness; and he has obtained from them many existing species of terrestrial and fluviatile shells, as well as scales of fishes.

If we follow these highly-tilted clay and conglomerate beds towards the centre of the valley of Kashmir as we can well do along the main road from Gulmarg, where they are greatly developed, we shall find that as we advance towards Srinagar the dip of the beds gradually decreases, until it is not more than a very few degrees from the horizontal; while at the same time the conglomerates and blue clays disappear and are replaced by light-colored sands and loamy clays, bearing very distinct marks of stratification. Finally, as we get within a few miles of Srinagar (beyond which place these deposits have been denuded away), we find that the strata are almost, if not quite, horizontal.

It is, therefore, apparent that we have been crossing the strike of a continuous formation, the lower beds of which are tilted and often conglomeritic, while the upper beds are nearly horizontal and sandy or clayey. There is no sign of any break in this formation that I can detect, and I should think that at a low estimate it cannot be less than one thousand feet in thickness.

Turning now to the opposite side of the valley, and taking the section near Pampúr as a typical instance, we find here also a considerable thickness of stratified clays and sands which are perfectly horizontal; these seem to correspond to the topmost sandy beds on the opposite side of the valley. Mr. Drew says (*sup. cit.*, p. 209) that similar beds to the north of Islamábád attain a thickness of from 250 to 300 feet. Below these sandy beds, north of the latter place, there occurs a considerable thickness of limestone conglomerate, resting conformably on a sloping surface of the carboniferous limestone, and itself sloping also, according to Mr. Drew, at an angle of from seven to fifteen degrees.

The whole of the horizontal sandy deposits to the north-east of the valley, together with the upper sandy deposits of the south-western side, I propose to call the upper Karewahs; while the tilted clay and conglomerate beds along the Pír Panjal I shall designate as lower Karewahs. There is no evidence to prove that the conglomerate underlying the upper Karewahs at Islamábád is contemporaneous with that of the lower Karewahs at Bámúla, and I am inclined to take Mr. Drew's view that it formed an ancient lake beach, and was deposited on a sloping shore.

On the south-western side of the valley of Kashmir it is quite clear from the presence of the tilted Karewahs that a very great disturbance has taken place along the Pír Panjal range since the period of the deposition of these Karewahs; this disturbance has elevated the beds of the lower Karewahs to an angle of more than twenty degrees in certain places, but it does not seem to have extended inwards to the centre of the valley of Kashmir. It is important to notice that the strike of this disturbance coincides in direction with the strike of

the disturbance which has raised the Siwaliks of the outer hills into their present position; the Karewahs, however, differ from the outer Siwaliks in that the dip of the beds inclines away from, instead of towards, the adjoining range.

This tilting of the Karewahs, together with the great amount of denudation which they have subsequently undergone, serves to indicate that these deposits are, relatively speaking, of very great age; and I am inclined to think that, at all events, the lower Karewahs cannot be much, if at all, newer than the upper Siwaliks of the outer hills, and that therefore they probably belong to the top-most pliocene or pleistocene period. I am the more inclined to adopt this view, because we know that in the outer hills the period of disturbance did not extend to the epoch of the Post-Siwalik deposits, which are in all cases horizontal; and it seems to me most probable that the same general disturbance acted as well on the Kashmir Tertiaries and Post-Tertiaries as on the Siwaliks, but that it may perhaps have lasted a little longer in the former area.

Mr. Drew has already pointed out the distinction between the modern alluvium of Kashmir and the Karewahs, and he has also shown that, at all events, the greater part of the former was deposited before the date of the construction of any of the ancient buildings of Kashmir, but how much before we do not at present know; as far as this evidence goes, it all points to the great age of the Karewahs.

I do not here propose to enter into the question of the mode of deposition of the Karewahs, as this has already been discussed by General Cunningham, Mr. Drew, and others; I will, however, here mention that I think there can be no doubt but that the above writers are perfectly correct in assuming that these deposits have been formed in the bed of a vast lake which once covered the whole of the valley of Kashmir.

Below Baramúla, the valley of Kashmir is now bounded by a low ridge entirely formed of fluvial deposits; this ridge evidently forms the remnant of much larger deposits, which once extended lower down the Jhelam valley, but which have subsequently been removed; it seems, therefore, clear that the old lake must have extended lower down the Jhelam valley than the present boundary of the valley of Kashmir, until it was stopped by some dam. It is not improbable that this old dam existed in the narrow gorge through which the river now flows at Rampúr, some ten miles below Baramúla, this gorge having been deepened out since the Karewah period. At page 171 of the "Wanderings of a Naturalist in India" Professor Leith-Adams appears to consider that the Baramúla gravels were formed by a glacier which dammed Kashmir at this place. The regular stratification of these gravels appears to me to be against this view of the case.

There does not now appear to be any trace of Karewah deposits remaining in the Jhelam valley between Baramúla and Rampúr; these having been all removed and replaced by more recent river deposits,—another proof of the age of the Karewahs.

I am not sure to what extent the Karewahs formerly extended up the eastern end of the valley; at the present time (as is shown on the map) the whole of the country about Sagám is covered only by modern river alluvium, generally above the level of river deposit, which is at once distinguished from the Karewahs by

the absence of stratification. Lower down in the valley, as at Kailgám, the modern alluvium still exists in considerable force, but the yellow and blue clays of the Karewahs are exposed in the river sections; still further west, as near Shapiyan, the Karewahs generally form the surface soil, though near the river valleys they are often covered with a boulder deposit of more modern origin.

II.—THE OLDER ROCKS OF THE SOUTH-EAST OF THE VALLEY OF KASHMIR.

In my previously published notes on the geology of the Pír Panjal, I have already given some account of the rocks composing that range, more especially those on the outer side; in that paper, following former writers, I assumed the probability of the Cambro-Silurian age of these rocks. I may now state that during the present season's work the same rocks have been traced across the valley of Kashmir, and have been there incontestably proved to be in great part of Silurian age, though some of their lower beds may be Cambrian. In the present account these rocks will generally be referred to as the Panjal or Silurian series.

Before commencing the description of these rocks in the Kashmir valley it may be as well to state here, that wherever the word *slate* occurs, it is used in the wider sense, not implying distinct cleavage. I may also mention here that in the map accompanying my paper on the "Geology of the Pír Panjal," the Panjal rocks are referred to as "crystalline schists," whereas they should have been referred to as slates and amygdaloids.

It may also be not out of place here to refer shortly to the amygdaloidal rocks of the Pír Panjal and other parts of Kashmir, before proceeding to describe any of the sections; this is the more advisable, because in my previously-quoted paper on the geology of the first-mentioned region, I discussed the question as to the volcanic or metamorphic origin of these rocks, a question which I then left still in great part *sub judice*, though I inclined somewhat to the theory of their metamorphic origin.

If our researches were confined to the Pír Panjal range, we should, I think, have but little prospect of arriving at any very definite conclusion as to the mode of formation of the rocks in question, since in that region these rocks always occur interstratified with the slates, and their composition is often such that we cannot in the field predicate either their igneous or metamorphic origin. If they be trappean, they must be, as will be gathered from my former paper, of contemporaneous origin with the slates, and therefore we are debarred from any evidence which might have been afforded by dykes as to their trappean origin.

On the north-western side of the valley of Kashmir, however, near Srinagar, and in the Sind valley, there exists a formation which agrees with the series of the Pír Panjal, in containing certain amygdaloidal rocks very much resembling those of the latter region. These amygdaloidal rocks of the Sind valley, however, differ in their association from those of the Pír Panjal; instead of being interstratified with slates, as in that range, and the whole series showing a markedly stratified appearance, these rocks are mingled with a compact greenstone-like rock, and with another granular greenish rock, like anamesite; the greenstone-like rock frequently contains large pear-shaped nodules of chalcedony, and small needles of a mineral, which is, I think, chrysolite. The whole formation is entirely

devoid of any signs of visible stratification, and forms bold massive cliffs, very different in appearance from the slates of the Pír Panjal.

I cannot but think, both from the physical appearance, and from the composition of these rocks (and more especially from the presence of chrysolite and nodules or amygdala of chalcedony) that they are, in great part at least, of eruptive origin; although some of their upper beds may have been brought into their present state by the aid of metamorphism.

Assuming then the, at all events, partly eruptive origin of these Sind valley rocks, it remains to see what relation they bear to the thin-bedded amygdaloids of the Pír Panjal. Now, these presumably eruptive Sind valley rocks underlie the carboniferous limestone; they do not, however, penetrate into this limestone, which must have been the case were they intrusive trap; we can, therefore, only presume they are of contemporaneous origin with the rock series with which they are associated,—that is to say, that they are of *infra*-carboniferous age, or of the same age as the upper slates and amygdaloids of the Pír Panjal range. It may be observed in passing that, even regarding these rocks as eruptive and contemporaneous, it is remarkable that no case of intrusion should have been observed in connexion with them. This important evidence is wanting to finally decide the question of their origin.

The rocks of the upper Panjal series must be therefore contemporaneous with the trappoid rocks of the Lower Sind valley, and if, as seems to be the case, the latter be of eruptive origin, it would seem probable that some of the amygdaloids of the Panjal are likewise of eruptive origin, although there is a gradual transition from the typical amygdaloids to the slates, which, in some cases, may perhaps be due to the effect of metamorphic action, or to the original commingling of detrital and eruptive matter.

On the eruptive hypothesis of the origin of the amygdaloids in the two areas, it remains to be considered why in one area they are associated with slates and in the other with rocks of more decidedly igneous characters. Now, I think the most probable explanation of this difference is that in the upper Panjal period, there were a number of small and intermittent flows of trap in the area of the Pír Panjal range, and that deposition of mud went on regularly in the intervals between these flows; moreover, these flows of trap seem to have been too thin to have produced greenstone-like rocks, all of them being more or less amygdaloidal or vesicular, and indicating no great pressure from above. In the greater part of the Sind valley area, on the contrary, there seems generally to have been exceedingly little trap poured forth among the slate series which underlies the carboniferous limestone, but in the Lower Sind valley and near Srinagar we have a vast mass of trap which was poured forth immediately before the deposition of the carboniferous limestone, and which seems to have been extremely local, since higher up the Sind valley (*—infra*) we find pure slates underlying the carboniferous limestone. This Lower Sind valley trap was of such thickness as to have produced greenstone-like rocks in its lower portion, where the pressure was greatest; while in its higher portion, where the pressure was of course far less, we find amygdaloidal and vesicular rocks, like those of the Pír Panjal; mingled with rocks which may be altered slates.

According to this view, the massive trap and trap-like rocks of the Sind valley are only amplifications of the thin-bedded trap of the Pír Panjal, and both are the equivalents in time of the simple slates which in many other places underlie the carboniferous limestone. This identification of the two trappoid rocks is, of course, independent of any theory as to their origin.

In many other parts of Kashmir and the neighbouring districts trap-like rocks are found in greater or less force among the Silurian slates, but never extending up into the carboniferous period. It is impossible to indicate all the occurrences of these trap-like rocks in a small-scale map, and by means of the necessarily imperfect survey which is all that can be attempted in these somewhat difficult regions. Where, however, these rocks occur in considerable force, they are indicated by crosses in the slate series; no attempt has, however, been made to distinguish between the thin-bedded amygdaloids of the Pír Panjal, and the massive greenstone-like rocks of the Lower Sind valley and Srinagar.

The interstratified amygdaloids of the Pír Panjal, taken together with the peculiar conglomerate referred to in my previous memoir on that range, afford us valuable aids in recognising those rocks in other districts. These amygdaloids are most abundant on the outer sides of the Pír Panjal range, and in the neighbouring parts of Kashmir also extend into the Wardwan valley and into Kishtwar, where, however, they are in much less force, the slates and sandstones there predominating.

Specimens of these varieties of the trappoid rocks of Manasbal near the Lower Sind valley have been forwarded to Colonel McMahon, who has made sections of them for microscopic examination, some of which, together with his notes, he has kindly sent to the Indian Museum; it is from these notes that the following observations have been compiled. The specimens sent comprised a finely porphyritic rock, which will be designated as A; a compact rock, which, we will call B; and an amygdaloid, which we will call C.

Colonel McMahon considers that A is undoubtedly igneous. Crystals of white felspar occur abundantly in this rock, having their axes turned in all directions, in a manner which is very characteristic of trap-rocks. Since its igneous liquefaction, this rock has been altered by aqueous metamorphism; this is rendered evident by treating the rock in the matrass, when on the application of a moderate heat (very far short of a red-heat) it readily gives off water. When thus treated this rock also gives off an acid vapour; it also answers to the silver test for sulphides, and therefore probably contains iron-sulphide, though crystals of this mineral (pyrite) were not satisfactorily observable under the microscope. The other results of the metamorphism which has taken place subsequently to the cooling down of the rock are clearly visible. Masses of green chlorite are very prominent here and there, while the felspar crystals, which seem originally to have been pure triclinic prisms, are now clouded with flocculent, chloritic matter, which has impaired their pristine translucency; even now, however, under the polariscope, polychroic tints are here and there distinctly displayed. The clouding of the felspar crystals due to metamorphism has nearly obliterated all traces of the twin-crystals of the triclinic system, but portions of these seem to be still

remaining in some of the sections, if we may judge by the parallel bands of color, (so characteristic of the triclinic feldspars) which appear in certain of the crystals. This rock fuses readily into a bead, and contains 54.1 per cent. of silica.

The rock designated as B appears to consist of an iron-silicate disseminated in thick, flocculent masses through a felspathic base; it shows no traces of a crystalline structure; and it may be a trap or it may be an altered slate. The iron-silicate in this rock does not appear to be hornblende, since the whole of its coloring matter is extracted by hydrochloric acid. This rock also contains a considerable amount of hydrous minerals, which readily give off water in the matrass, on the application of a moderate heat; it contains 62.9 per cent. of silica, 30 per cent. of alumina and iron, a considerable quantity of lime, and a small quantity of magnesia. As far as its chemical composition goes, there is therefore no reason why this rock should not be a trap; the absence of distinct crystalline structure is somewhat against this view, though Colonel McMahon mentions that certain rocks from Edinburgh described as basalts do not exhibit crystalline structure. Colonel McMahon suggests that it is not impossible that this rock may be a sub-aqueous volcanic product, such as ashes deposited in the form of mud on a sea-bottom, or the product of the sub-aërial erosion of trap.

The amygdaloidal rock C according to Colonel McMahon appears to be a trap, since it shows the same quaquaversal arrangement of the feldspar crystals which was observed in A; this peculiar structure Colonel McMahon considers could not be produced by aqueous metamorphism. As was the case with A, this rock also shows abundant signs of subsequent metamorphism, patches of chlorite occurring in many places in the crystals; the rock was probably at first a porous or scoriaceous, igneous product, and has been subsequently altered by the infiltration of extraneous substances through its pores.

The above observations of Colonel McMahon on the Manasbal rocks are of great importance; from these observations it appears to be pretty evident that at least some of these rocks are of igneous origin, and it is further evident that all of them have been altered by subsequent metamorphism. The resemblance of the amygdaloids of the Pír Panjal to those of Manasbal, which we have already referred to, renders it probable that some of the former are also of igneous origin. A greater amount of subsequent metamorphic action in one part of Kashmir than in another, would account for the discrepancy in the character of the rocks which so often occur. Thus at Manasbal this metamorphic action appears to have been of great force, and has not improbably merged both slates, trap-ashes, and perhaps true traps into a homogeneous rock like B, which is intercalated with, and in the mass indistinguishable from, true trap rocks like A and C; in the Pír Panjal, on the other hand, the metamorphic action has been less strong, and has not generally altered the slates, except perhaps occasionally near the amygdaloids, into a rock resembling trap. In the one area the whole rock-series looks like an igneous rock, and shows no signs of stratification; while in the other the igneous rocks occur generally as thick bands in the aqueous, and the series taken as a whole consequently shows very distinct signs of stratification. Intermediate states of metamorphism, coupled possibly with a greater or lesser eruption of ashes, would account for the condition of rocks which, like those of parts of the

upper Lidar valley, are intermediate in character between those of Manasbal and those of the Pír Panjal.

We may now continue our survey of the Panjal series, which, in my already-quoted paper of that region, we had traced across the range to Báramúla. Travelling along the foot of the north side of the range from the latter place towards the east, we find that the rocks consist of blackish slates, with a few bands of white quartzite, and others of little altered green or greyish sandstones. Further to the south-east, near the village of Poshgar, the amygdaloidal traps interstratified with slates are in considerable force; these rocks have a south-westerly dip and the normal north-westerly strike which prevails along the whole of this side of Kashmir; the south-westerly dip continues along the range as far as the town of Kúlgám; a little to the east of this place, near the village of Gúndpúra, we come upon a north-easterly dip, which is the continuation of the anticlinal and synclinal axes which were noticed in my previous paper as occurring to the south-west of the Banihal pass, and which cross the range into Kashmir at its bend to the west of the pass.

Throughout the above-mentioned area the Panjals maintain their normal character, consisting of slates and amygdaloids with some sandstones; the amygdaloids are, however, less prevalent to the eastward than in the centre of the range. The matrix of these amygdaloids is nearly always of a compact texture, and green in color: the amygdala are generally greenish-white in color, but are sometimes green, of a darker hue than that of the matrix; the amygdala are too hard to be scratched by the knife, and in places undoubtedly pass into nodules of chalcedony. Near the village of Gúndpúra the amygdala are generally quartzitic or chalcedonic in character; these are usually pear-shaped, and often as much as three inches in diameter.

In the bed of the river flowing from Gúlmarg, as also in the Yechari, and other streams, pebbles of gneiss, similar to that found to the south of the Banihal pass, are of common occurrence; this affords us proof that the same band of gneiss extends along the Pír Panjal range to the westward of the latter place, although I have not yet had an opportunity of tracing its boundaries.

I have already mentioned, in my previous paper, the occurrence of a band of conglomerate on the south side of the Panjal range. In a section taken by Mr. Theobald across the Mohun pass, this band was found *in situ*; it occurs at a considerable distance above the gneiss, apparently somewhere near the middle of the Panjal group.¹

Taking now a section across the Pír Panjal pass to the outer hills, we find the following series of rocks. A little above the village of Hirpúr we leave the sandstones and conglomerates of the lower Karewah series, and come upon a series of green rocks with very indistinct stratification; some of these rocks are amygdaloidal, and from their resemblance to the upper amygdaloidal trap of the

¹ I may here mention that Professor Leith-Adams, at page 214 of his "Wanderings of a Naturalist in India," speaks of the finding by a native shikari of an ammonite near the village of Tortiana on the Panjal. I cannot but think that this specimen was not authentic, as we have very good reason to believe that the whole of the Panjal rocks are palæozoic. The specimen was probably derived from the triassic rocks of the opposite side of the valley of Kashmir.

opposite side of the valley of Kashmir, must probably, as we have seen, be considered as of eruptive origin; it is, however, in many cases extremely difficult to decide in this region whether certain of these green rocks are of eruptive origin, or whether they are metamorphosed sedimentary rocks.

Proceeding further up the Hirpúr valley, and approaching the old Mogul halting place of Dabchi, we find these amygdaloidal rocks underlaid by black slates with a north-easterly dip; at Dabchi itself there is a small anticlinal and synclinal fold in these slates. Above Dabchi we have a continuous descending series of slates mingled with a few bands of conglomerates which contain quartzitic and slate pebbles, till some distance below Aliábad serai, where we find buff and white quartzites underlying these slates; near the latter place we again come upon black slates which underlie the quartzites: these slates contain rounded and angular masses of gneiss. Immediately above Aliábad serai we come upon granitoid gneiss underlying the black slates with the same north-easterly dip; the gneiss includes a few bands of slates and quartzites.

This gneiss continues nearly to the summit of the Pír Panjal pass, and bears to the north-west, along the ridge of the Chitta-Pani and Chota-Galli passes. Near the Pír Panjal pass the beds of the gneiss are almost vertical; still nearer the summit of the pass we come upon black slates with imbedded gneiss pebbles apparently underlying the gneiss, and, again, similarly underlaid by whitish quartzites which form the summit of the pass. On the south-western side of the pass we have a regular series of rocks with a north-easterly dip apparently underlying the quartzites; these consist of slates, sandstones and conglomerates similar to those of the opposite side of the pass, only that the latter rocks are in greater force on the south-eastern side. These slates and conglomerates continue nearly to Baramgalla, where we find amygdaloidal rocks interstratified with the slates: these slates and amygdaloids continue with the same north-easterly dip till we come upon the limestone rocks of the Suran river, which have been mapped in my previously published paper on the geology of the outer side of the Pír Panjal range.

From the above description it will be apparent that on the north-east side of the Pír Panjal we have the following series of rocks, counting from the highest to the lowest, *viz.* :—

1. Greenish slates and sandstones and amygdaloidal rocks.
2. Black and green slates with brown sandstone conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
4. Black slates containing pebbles of gneiss and quartzite.
5. Granitoid gneiss with occasional bands of slate and quartzite.

If now we turn to the rocks on the southern side of the gneiss, we shall find that they present the same series, only in the reverse order; the uppermost rocks of the north-eastern side being the lowest on the south-western side, and *vice versa*.

This section therefore seems to be only explicable in the same manner as that across the Banihal pass (of which I gave a diagram in my previous paper), namely, by the inversion of all the strata on the south-western side of the range. The

gneissic strata must, therefore, form a great anticlinal axis conformably underlying the slates on either side; this gneissic ridge, however, is not altogether continuous, as it does not occur in the gorge at the bottom of the Jhelam valley, where the slates, much contorted, form the whole section, and apparently bend round the masses of gneiss existing in the hills on either side of the valley.

According to this view the limestones of the Suran valley, which I presume to be inverted, are, as I supposed in my former paper, the topmost beds of the Pír Panjal series, and are probably, as I shall show subsequently, of carboniferous age!¹

The presence of gneissic pebbles in the Panjal conglomerates must probably be accounted for by transport from other outcrops of gneiss, as the gneiss of the Pír Panjal is conformable to the overlying slates, and could not have been denuded at the time of the deposition of the latter.

Having now traced the slates and amygdaloidal rocks of the Pír Panjal range along the greater portion of the south-western border of the valley of Kashmir, we may cross to the opposite or north-eastern side of the valley, and proceed with our survey. Taking the city of Srinagar as our starting-point, and proceeding thence to the neighbouring hill called the Takt-i-Suleiman, we find that the rocks on the western side of that hill are massive, and without any stratification, of a greenish color, and either homogeneous or amygdaloidal; the same rocks also form the small hill on which is built the fort of Hari-Parbat. These rocks are the same as those which we have already referred to in the Lower Sind valley, and which we shall again have occasion to refer to, and, as we have seen, are probably to a great extent of trappean origin.

To the eastward of the Takt-i-Suleiman, we come upon a band of black and green slates, which, towards the north-west of Zebanwan station, is overlaid by calcareous sandstones, cherts, and slates; near the Nishat Bagh these rocks have a northerly strike and dip towards the trap-like rocks which compose the main range to the north-east; the sandstones contain imperfect fossils, but too broken for identification.

I think that the lower slates near the Takt-i-Suleiman, from their resemblance to other rocks, belong in all probability to the Silurian or Panjal period, while the overlying calcareous and arenaceous rocks have a great resemblance to the lower carboniferous rocks of the Marbal pass, which we shall subsequently discuss, and may very possibly be the equivalents of these rocks, though in the absence of any definite proof to this effect, and for reasons to be noticed immediately the rocks are all of one color in the map.

Now comes the question as to the relation of these slate rocks to the trap: we have already seen that the former dip towards the latter, and we have also seen that the latter in the Lower Sind valley underlies carboniferous rocks, and is consequently of high Silurian age; this would tend to show that the slaty rocks

¹ In my former map of the Pír Panjal region the limestone series is not represented as occurring to the north of Rajaori; I, however, now find that this is incorrect, as limestone bands do occur there, mingled with the slates at the apparent base of the series, which belong to the same zone as the more massive limestones to the east and west.

are not of upper Silurian and carboniferous age, as otherwise they ought to overlie the trap conformably, but that they may be of lower Silurian, and have been brought into their present position by faulting, which would well explain the relations of the two. I can, however, at present say nothing certain on this somewhat difficult point.

Proceeding from Srinagar towards the south-eastern extremity of the valley of Kashmir, we find that the same trap-like rocks form the spurs bounding the Pampúr valley; the upper part of the valley to the north of the latter place is occupied by a lenticular mass of carboniferous limestone, with a north-easterly dip, and which apparently overlies the traps, though the relation is in places disturbed by faulting.

I am not sure as to the nature of the northern boundary of this mass of carboniferous limestone, but I fancy that it is a faulted one. Beyond the limestone we again have trappean rocks, underlaid to the north-east by slates, which we shall subsequently trace from the Lidar to the Sind valley.

It may be well to state here, before going any further, that in the Lidar valley the slate series is overlaid conformably by carboniferous rocks, and must consequently be of silurian age. In the Sind and Nowbúg valleys, moreover, the same slates will be shown to be the equivalents of those of the Pír Panjal, the latter also being consequently of silurian age; these slates of Kashmir will therefore often be referred to as Panjals.

At the mouth of the Lidar valley the silurian slate series is interrupted along the axis of the valley of Kashmir by carboniferous rocks; to the north of the latter rocks, however, the slates are continued; their eastward extension will be discussed in subsequent sections.

The carboniferous rocks of the south-east of the valley of Kashmir occupy an irregular ellipsoidal area in the midst of the silurian slates and trap-like rocks: to the westward the former rocks are bounded by the alluvium of the Lidar valley, where we shall again refer to them in the section from Islamábád; there is a small outlier of the older rocks at the latter place. The valley of the Arput river has cut a wide gap in these rocks, to the eastward of which they recur at Achibal, where, as well as at Islamábád, they dip at a low angle to the north-east; another ridge of the same rocks runs near Sháhábád, and disappears to the north-west beneath the alluvium of Kashmir; the beds on the south-western side of this ridge have a north-easterly dip, while those on the opposite side dip to the south-west.

Towards the south-west these carboniferous rocks extend as far as the northern flank of the Banihal range, where I have already referred them in my "Notes on the Geology of the Pír Panjal." At this junction they have a south-westerly dip, and are faulted against rocks of the Panjal series with a north-easterly dip. To the eastward the carboniferous ellipse extends a short distance beyond the Marbal pass, where it will be again referred to in the section from Kishtwar to Kashmir. The north-eastern boundary is very irregular; in the Arput valley it occurs between the villages of Watúsú and Kor and then bears across to Nowbúg; here the Panjal rocks cut into the middle of it from the south-east; and the inner boundary is a continuation of the line of the Tansan river from

the village of Wyl; from the latter place the Tansan river forms the boundary between the carboniferous and Panjal rocks, as far as the village of Prúma, from whence the boundary again sweeps towards the north-east, and thence again southwards to the Marbal pass.

It will be clearly understood from the above, that the carboniferous rocks of the valley of Kashmir, are, except to the westward, bounded by rocks of the Panjal series; and it may be well here to make a few remarks on the carboniferous series of the valley of Kashmir.

The ridge to the north of Sháhábád, on which stands the station of Hazrat-Ziarat, offers a fair section of the carboniferous limestone, which is here selected for description; the rocks composing this low ridge have a north-easterly dip of about forty-five degrees; the lowest beds exposed consist of dark blue limestone often containing crinoid stems in considerable abundance; in the higher beds this limestone gradually assumes a cherty character, till finally, at the summit of the ridge, it passes into a compact and fine-grained sandstone, of a brownish-yellow color. To the north-east of this ridge there occurs a synclinal axis running through the topmost sandstones; in this synclinal the sandstone is in places almost white, with minute red ferruginous specks.

Passing further to the north-east, we find, at the foot of the ridge to the north-east of the town of Ságam, an anticlinal axis, which brings into view beds still lower in this series than any of those shown in the Hazrat-Ziarat ridge. The beds at the foot of the first-mentioned ridge have a south-westerly dip, while those further on dip towards the north-east. The lowest beds consist of dark-brown sandy shales, gradually becoming calcareous, then containing distinct nodules of limestone, and finally passing into the characteristic dark blue, carboniferous limestone, with crinoids and other fossils. The underlying shales have frequently a bacillar structure; the exposed beds below the limestone have a thickness of about sixty feet, but their base is not visible; these beds are readily distinguishable from those which overlie the limestone, by being more shaly, less compact, and of a darker and duller color; they contain no traces of fossils. The series may be tabulated as follows from above downwards:—

1. Yellowish and whitish sandstones.
2. Blue limestone.
3. Shales, with limestone nodules.
4. Shaly sandstones.

Whether the whole of the four groups of beds noticed in the above table should be referred to the carboniferous series I am unable to say, as no fossils have been found here either in the highest or the lowest beds.

With regard to the highest beds, which are often replaced by banded limestones, I can only say that they very probably represent some of the triassic beds which overlie the carboniferous limestones in other areas, but that, in the absence of fossils, we cannot be sure of this. Some of the underlying shales may very probably belong to the upper Panjal or Silurian series.

It may not, perhaps, be out of place here to mention the springs of water which, at Vernag, Achibal, Bowan, and Islamábád, burst forth from the bases of

cliffs of the carboniferous limestone. These springs are of such volume as to form small rivers at their origin, and take a considerable part in forming the waters of the upper Jhelam. At the two first-mentioned localities the springs rise from the base of cliffs situated at right angles to the strike: while at the two latter they rise from true escarpments. It seems difficult to account for the welling up of such great volumes of water, without calling in the aid of faults, although the relation of the rocks to neighbouring outcrops does not lend much countenance to this hypothesis.

The rocks at the north-western extremity of the valley of Kashmir I have at present only partly examined. To the north of Srinagar as far as the Sind valley, I have not surveyed the rocks: the rocks of the valley beyond the Sind river will be found described in the Amrnath and Sind valley section.

III.—SECTION FROM ISLAMÁBÁD TO AMRNATH, AND FROM PALGAM TO SIND VALLEY AND NORTH-WEST KASHMIR.

Passing up the Lidar valley from Islamábád, we have, on the left bank of the river, rocks of the carboniferous series, as far up as the village of Hút-morú; at Bowan these rocks consist of dark blue limestone, with a north-easterly dip; above Bowan there are several flexures, and slates and sandstones are mingled with the limestones. North of Hút-morú we come upon rocks of the Panjal or silurian series, consisting of chloritic slates and sandstones, with a few amygdaloids; their dip is at first north-east.

These Panjal rocks continue as far as the village of Eishmakám, where they are overlaid conformably by a series of green and white sandstones, blue limestones, and then by blackish slates and sandstones. The limestones contain crinoid stems, and two genera of corals very closely allied to the genera *Zaphrentis* and *Cyathophyllum*; the overlying slates and sandstones are full of *Fenestella*, *Productus*, and *Spirifer*, of carboniferous species. The series at Eishmakám may be tabulated as follows, from above downwards:—

- | | |
|--|-------------------|
| 1. Slates and sandstones with <i>Fenestella</i> , <i>Productus</i> , and <i>Spirifer</i> | } Carboni-ferous. |
| 2. Sandstones and dark blue limestones with corals and crinoids | |
| 3. White and blue sandstones | } Silurian. |
| 4. Blue or green slates and amygdaloids= | |

This section proves the silurian age of the slate series of this part¹ of Kashmir, while the next section will show that these slates are the same as those of the Pír Panjal. It will be observed that the carboniferous rocks of Eishmakám have precisely the same relationship to the Panjal series as have the Kiol series of the outer hills to the same rocks; the two overlying series are also very similar in mineralogical composition. In my "Notes on the Geology of the Pír Panjal," I suggested that the Kiol group was of upper silurian

¹ It may be well to observe here that in the more eastern Himalayas, there is no distinct Devonian period; and the same rule is held to prevail here. Similarly we may notice the absence of any distinct permian period in the more eastern Himalayas, and probably also in the more western; *vide infra*.

age; the present section, however, makes me think that it must be of carboniferous age.

The carboniferous rocks of Eishmakám continue nearly up to the village of Bhatkot, where we come upon a bold escarpment of amygdaloidal and greenstone-like rocks, which seem to be faulted against the carboniferous rocks, cutting them out to the south-east along the ridge on which stands Liwarpatar station. Above the traps we have rocks consisting chiefly of massive blue and green sandstones and some amygdaloids; as these traps are overlaid by slates, and are not in close relation to the carboniferous series, they may probably be somewhat lower in the series than those of the Sind valley and Pír Panjal. To the west of the Lidar river, the carboniferous rocks seem to be faulted against the trap of Churn station.

The Panjal slates continue nearly as far as the village of Palgám; near the latter place we come upon another outlier of carboniferous limestones and slates, overlying the Panjals; on the Shisha-Nag road to the south-west of Praslung the Panjals again come in beneath the carboniferous limestones, which have here a northerly strike and westerly dip. The Panjals here consist chiefly of slates and bluish-green slaty sandstones, partially metamorphosed.

The same Panjal rocks continue to Chandanwari, where they have a north-easterly dip, and underlie the white sandstones and dark blue limestones of the carboniferous series, which here stretches in a south-easterly direction below the Shisha-Nag into the Wardwan valley; the Panjals in places contain a few beds of amygdaloids interstratified with the slates.

Taking a direct section from Chandanwari across the strike to Amrnath, *viâ* the Koun-Nag, we find that the dark blue carboniferous limestones (containing corals and crinoids) are interstratified with thick beds of slate and sandstone, and continue nearly up to Aston-Marg; at the latter place bands of white dolomitic limestones become common, and beyond this the series consists of almost pure white dolomite with the same north-easterly dip up to the Koun-Nag; here we find the dolomites overlaid by light blue limestones, sandstones, and slates; further in still (to the west of Panjtarni station) the strata consist entirely of slates and sandstones overlying the limestones; near this place the strata are greatly disturbed by contortions. Further north, however, to the south of Panjtarni halting-place, we again come upon strata of white dolomite, with a south-westerly dip, which immediately underlie the slates and sandstones of Panjtarni station without any intervening limestones; these slates will consequently be the highest of the series in this district.

Taking the road to Amrnath *viâ* Nag, we find that to the north of Panjtarni the strike of the white dolomites has become due north and their dip due west; about a mile to the east of Nag, the dolomites are overlaid conformably by slates and sandstones, the former with a bacillar structure. These slates and sandstones are continuous with those of Panjtarni, and to the west of Amrnath cave strike into the Zoji-la pass, where they form the "bacillar sandstones" noticed by Dr. Stoliczka at page 349 of "Observations in Western Tibet."

The dolomites strike through the station and sacred cave of Amrnath and appear again on the Dras road to the north-east of the Zoji-la pass, and are

here continuous with rhæto-triassic strata, described by Dr. Stoliczka, which we shall again refer to. To the east of Amrnath we have a descending series of limestones and dolomites; these rocks are more blue in color, to the west, and may probably be in part carboniferous.

The dolomites and limestones to the south of Panjtarni station also bear round to the north, and seem to be continuous with the triassic limestones and slates described by Dr. Stoliczka, on the Kashmir side of the Zoji-la.

In a section from Shisha-Nag to Panjtarni, we have much the same rock-series as from Chandanwari, except that immediately below the slates of Panjtarni station, the dolomites are mixed with sandstones, slates, and light-blue limestones, in place of being nearly homogeneous as at Aston-Marg.

As to the age of the above strata, we have seen that the slates and limestones of Chandanwari are carboniferous; the strata above this blue limestone do not contain recognisable fossils, but belong in all probability to the triassic period.

The dolomites of Amrnath are continuous with the dolomitic limestones north of the Zoji-la, which Dr. Stoliczka considers as equivalent to the Para limestone. The similar dolomites to the south of Panjtarni, which we have seen are partly replaced to the eastward by limestones and sandstones, will consequently be of the same age, and, as I have said before, seem to be continuous with the undoubted triassic limestones to the south of the Zoji-la.

There now only remains the question of the slates and sandstones of Panjtarni, and the sandstones of the Zoji-la; the latter were considered by Dr. Stoliczka to underlie the triassic limestones and consequently to be of carboniferous age; it, however, appears that the section was not clear, and we must consider it to be a case of inversion, since we have seen that these slates and sandstones most distinctly overlie and occur in a trough of the dolomites which occur to the south-east of the Zoji-la. As before said, therefore, these slates must be the highest beds of the rhæto-triassic series.

The dolomites to the north-east of the Zoji-la, according to Dr. Stoliczka, overlie the triassic limestones; the same limestones must therefore be represented to the east of Amrnath; while still further east I think the underlying strata must be carboniferous; these lower rocks would sweep round to underlie the triassic beds of the Dras river.

The strata of pure triassic dolomite are easily recognised from great distances by weathering into the most fantastically-shaped pinnacle crags; this is particularly well shown near Amrnath cave.

Returning now to Palgám, we have to continue our section to the north-west into the Sind valley; immediately to the north-west of Palgám, the limestones and slates of the carboniferous series continue as far as the village of Arú, where they are faulted against the silurian slates, and where they bend round to the eastward to join the Praslung boundary.

From this point to the Sind valley at Kúlan, we have a succession of chloritic sandstones and grey and black slates of the silurian series, intermingled with a few bands of amygdaloidal trap, with a north-easterly dip to the north of Lidarwat, and a south-westerly dip to the southward of this place. These silurian rocks continue as far as the north side of the Kolahoi range, beyond

which we again come upon the limestones of the carboniferous and triassic series, which, beyond Harbagwan, bend round with a west-north-west strike.

In the Sind valley to the north of Kúlan, the silurian rocks gradually entirely lose their chloritic and amygdaloidal character, and consist of black and greyish slates; a little to the south of Gaggangan these slates are succeeded by massive dark-blue limestones, with blue and white sandstones at the base, which, from their position, must undoubtedly belong to the carboniferous series, and which are doubtless continuous with the rocks of the same age and character to the north of Kolahoi. It is not improbable that some of the slates to the south of Gaggangan may also belong to the carboniferous series, though I have placed the boundary at the limestones as being the only distinct line.

These limestone rocks continue as far as the ridge on which stands Shalian station, at the base of which we come upon a fault; the rocks composing the latter ridge have a north-easterly dip, and at the base consist of amygdaloidal traps, overlaid by chloritic rocks, which are probably of metamorphic origin.

These rocks are probably of silurian age, and seem to have been thrust up in the middle of the carbonifero-triassic rocks (as we shall see immediately); I cannot, however, be certain as to what position they occupy in the former series; we have seen that the top of the silurian series which immediately underlies the carboniferous limestone of Gaggangan does not contain any trap, and it is therefore hardly likely that these rocks, irrespective of their position, are the same as those slates. I think it more probable that they belong to some lower silurian zone, which has been subsequently brought into its present position by faulting; this may, however, be a case of a local trap outflow and subsequent metamorphism of the upper slates.

This band of trap and silurian rocks continues to the south-east, forming the high range below Sonamarg; on the northern side of this range we come upon beds of light blue and banded limestones, white dolomites, and slates having at Thajwaz a south-westerly dip, and which seem to be faulted against the silurians. To the north of the last-mentioned village these limestone rocks have a north-easterly dip, and form a continuous ascending series to the northwards, where they are overlaid by sandstones and slates, similar to those of the Zoji-la and Panjtarni station; tracing these latter rocks along the ridge towards the Zoji-la, we find that they are inverted in several places, which accounts for Dr. Stoliczka's supposition that they were older than the limestones.

The Thajwaz banded limestones are very different from the massive dark-blue limestone of Gaggangan; from the fact that Dr. Stoliczka found a triassic ammonite almost at the base of the former series, it is clear that at least the greater part of the rocks to the north of the silurian band must be of rhæto-triassic age, and I have accordingly so colored them in the map.

To the east of Sonamarg, I have traced these triassic rocks up the Nichinai stream into the Kishenganga watershed; their distribution in the latter district must, however, be reserved for a future season's work.

Returning now to Kúlan, we have to follow the Sind river into the valley of Kashmir. Green and grey slates, with some bands of amygdaloids, and of the very characteristic conglomerate of the Pír Panjal, continue to the village

of Mamar; the occurrence of this conglomerate in the slate series of this side of Kashmir proves them to be the equivalents of the slates and traps of the Pír Panjal. On the right bank of the Sind river these slate rocks seem all to have a north-easterly dip; on the left bank, however, an anticlinal axis occurs below the village of Rewil; there is probably, therefore, either a break or a concealed fold among the rocks of the right bank.

Some little distance below the last-named village, we come upon an entirely different series of rocks; on the right bank of the river we find at the base of the cliffs (the dip being to the north-east) a considerable thickness of coarse gneissic rocks followed by unaltered grey sandstones, massive blue limestones, and overlaid by slates. The relation of these rocks to the silurians on the north-east is not well seen, but I think a fault divides them.

To the north-west and north these rocks are apparently faulted against a mass of what seems to be trap-like rocks, which we have already discussed. These trap-like rocks form a band extending from the east of Safapúr station towards Haramúk; similar rocks occur on the left bank of the Sind valley, but the exact division between these and the silurian slates is there also in great part concealed by forest.

At the northern side of the extremity of the spur, which forms the right bank of the Sind valley, we come upon dark blue massive limestones, which overlie the trap-like rocks, their strike being north-westerly, and their dip north-easterly. These limestones extend a little to the north of Safapúr station; to the west of this ridge we again come upon trap-like rocks, where a peninsula of these rocks extends into the middle of the limestone, and the latter has a quaquaversal dip around the trap.

To the south of the lake of Manasbal, at Aha-tang station, we have another mass of greenstone-like rock showing through the limestones; these limestones at and near Kandabal overlie the compact blue limestone, and consist chiefly of white dolomitic beds, which are identical in character with those of Amrnath, and which, I have not the least doubt, are likewise of triassic age. The massive blue limestone has not yielded characteristic fossils, though it contains crinoids, and brachiopods, and has yielded a species of *Orthoceras* to Mr. Theobald's search; there can, however, be not the slightest doubt from its character and position beneath the dolomitic beds, that it must be considered of carboniferous age.

The position of the presumably trappean rocks beneath the carboniferous limestone, shows that if the former be non-intrusive, they must be *pre-carboniferous*; while, on the other hand, if they be intrusive, they must be *post-carboniferous*.

From the form of their occurrence in a dome-shaped mass beneath the limestones, it might be supposed at first sight that these trap rocks were intrusive: the absence, however, of all dykes penetrating the limestone seems to forbid this view; and we can only conclude, as I have said before, that they are non-intrusive rocks, and are the representatives of the more thin-bedded amygdaloidal traps of the upper slates of the Pír Panjal.

We must now revert for a moment to the gneiss, sandstones, and limestones which occur between the trap-like rocks of the Sind valley, in order to endeavour

to find out their age. I must, however, first observe that the carboniferous series of Kashmir is liable to great variation in mineralogical composition, even in contiguous areas. Thus, we have seen that at Islamábád this series consists almost entirely of limestones; at Eishmakám, limestones are comparatively scarce, and sandstones and slates the prevalent rocks; while again at Palgám and Shisha-Nag, limestones predominate.

Now, it will be observed that these sedimentary rocks of the Lower Sind valley, if we except the lower gneiss, are almost identical in composition with the carboniferous rocks of Eishmakám; and I think it possible that they both belong to the same period; the lower gneiss beds would be the representatives of the sandstones of Eishmakám, which have been altered by some subsequent metamorphic action; which, as we have seen in the case of the trap-like rocks, has been strong in this area.

It is, I think, perfectly clear that these rocks cannot belong to the silurian series, in which limestone never occurs, nor do I think from their composition that they belong to the older gneiss, though Mr. Drew apparently favors that view.

In conjecturally referring them to the carboniferous period, however, a difficulty occurs, in that they are so different in mineralogical character to the neighbouring carboniferous limestones of the valley of Kashmir. The only way out of this difficulty, to my mind, is in considering that the carboniferous rocks of Kashmir were deposited in basins in a sea broken up by islets or peninsulas. The rocks deposited in deep water might well be chiefly calcareous, while those deposited in shallows and along the shores would consist of grits, clays, and a few calcareous bands.

This supposition would explain the difference in the two types of undoubted carboniferous rocks of Kashmir; the one exemplified by those of the upper Lidar valley, and Manasbal, and the other by those of Eishmakám. In the former series there is an almost unbroken succession of limestones through the carboniferous and triassic periods, while in the other the upper carboniferous beds are all sandy and clayey, and are not overlaid by trias.

The carboniferous limestones of Eastern Kashmir belong to the former type, though we cannot say for certain that they are overlaid by trias; at the Marbal pass, as we shall see, they are replaced by rocks of the second or littoral type.

The grits, clays, and limestones of the Lower Sind valley, if, as I think possible, they are of carboniferous age, must be the littoral deposits of the basin in which the massive limestones and dolomites of Manasbal were laid down. I cannot, however, be at all certain as to the age of these rocks, and have accordingly left them blank on the map.

Before proceeding to examine the rocks of the region of the Wular lake, it may, perhaps, be well to glance for a moment at the description of the rocks of the Sind valley given by Dr. Stoliczka at page 349 of his "Observations in Western Tibet." In justice to the memory of such an authority, it must, however, be observed, that his notices of these rocks were made on the evidence of a single hurried section, on his return from an arduous journey in Tibet; while my own observations are the result of a far wider survey. It is not, there-

fore, to be wondered at if some of Dr. Stoliczka's conjectural correlations of these rocks require certain modification at our hands.

In Dr. Stoliczka's Memoir, the triassic age of the Thajwaz limestones was proved by the occurrence of a characteristic ammonite; it appears, however, that the Shalian ridge of trap and probably silurian slates was not noticed, but that the Thajwaz limestone was supposed to rest directly on the massive limestone of Gaggangen; the slates underlying the latter were supposed to be of carboniferous age—a supposition which is in part quite likely to be correct, though the lower slates are silurian. The massive chloritic rocks, supposed to be of silurian age, seem to be in part at least the above-mentioned trap rocks, which we also have referred to the upper silurian series; the gneiss and limestones below Marmar are not noticed.

Commencing our survey of the rocks around the Wular lake, we find that trap forms the greater part of the rocks as far as the Budkool river, masses of carboniferous limestone, however, occurring along the borders of the lake, notably at Sadykut, Matipur, and on the left bank of the Budkool river. The limestones usually have a north-easterly strike.

To the north of the Wular lake, the trap-like rocks extend to a little beyond Kahati station, where they are overlaid by black, green and grey silurian slates, and green and buff sandstones, with an east-north-east strike, and north-westerly dip; on the supposition that the trap-like rocks are the highest silurians, this must be a case of inversion.

These slates and sandstones form the mountains surrounding and jutting into the Lolab valley; at Trigumma the green slates with a westerly dip are overlaid by massive blue carboniferous limestone, which forms the spur to the north-west of the latter place: a synclinal axis runs along this spur, and the limestones to the westward are again underlaid by slates: the lower beds of the former alternate on this side with beds of green slate.

The position of the Lolab slates, beneath the carboniferous limestone, shows that the former are of silurian age, and correspond with the slates of the Pír Panjal.

To the west of Shalúra we have various colored slates, white and green quartzitic sandstones, and amygdaloidal traps, all of which, I believe, are interstratified with the sedimentary rocks, and which must therefore belong to the silurian series. The sandstones and slates to the west of the Trigumma limestone are much more altered than those to the east, owing to the presence of the traps in the one area, and their absence in the other. To the south of Shalúra the silurian slates can be traced along the northern flank of the Kaj-Nag range to Baramúla, from whence we have already traced them along the Pír Panjal.

This section, therefore, again proves the identity of the slate series of the two sides of Kashmir, and also their silurian age.

IV.—SECTION FROM KASHMIR TO MARU-WARDWAN AND THENCE TO KISHTWAR.

Starting from the town of Ságam, we leave the semi-ellipse of the carboniferous limestone at the village of Panzgám or Panzgáma, and again come on the slates and amygdaloids of the Panjal series, which we have already traced along

the north-eastern boundary of the valley of Kashmir. At the village of Soap to the east-north-east of Ságam, there are very extensive iron works belonging to the Maharaja; the iron seems chiefly to occur in the form of carbonate and oxide at the base of the carboniferous series; Dr. Ince in his "Guide to Kashmir," when describing these works, mentions also the occurrence of silver and lead at the same place, and I have been shown specimens of the ore of the latter metal said to have been obtained from there.

The rocks of the Panjal series at Panzgám have a north-easterly dip of about fifty degrees and consist in great part of the amygdaloids, intermingled with slates and slightly altered sandstones.

At the village of Shátrú we come upon the semi-detached mass of carboniferous limestone, previously referred to, with a low north-easterly dip, extending as far as the town of Nowbúg, and both boundaries of which appear to be faulted. To the south of the Nowbúg outlier of carboniferous limestone, an anticlinal axis runs through the Panjal rocks, which seems to be continuous with the anticlinal which traverses the carboniferous limestone to the north of Ságam. The Panjal rocks to the south of Nowbúg are chiefly slates.

Between Nowbúg and the Margan pass the Panjal rocks form in the main a regular ascending series, interrupted by several minor flexures; for some distance above Nowbúg these rocks chiefly consist of amygdaloids, mingled with slates, while nearer the pass, slates and quartzitic sandstones are more prevalent; the slates are sometimes banded, but are more usually of a uniform olive-green color, marked with reddish ferruginous spots; at the top of the pass the rocks are mainly whitish quartzose sandstones. Throughout the series there are occasional bands of amygdaloids, while I also noticed numerous fragments of the characteristic conglomerate which has been referred to above as occurring on the Pír Panjal; I did not, however, observe this rock *in situ*; this was probably owing to the quantity of snow which lay on the pass at the time of my crossing.

A short distance to the north-east of the Margan pass a synclinal axis traverses the rocks, which must be high up in the Panjal series, and from thence we have a regular descending section with a south-westerly dip to the valley of the Wardwan river, repeating the series of rocks which occur on the south-west side of the pass.

The quartzose sandstones on and near the Margan pass exhibit very beautiful examples of "broad ripple;" the large slab of nearly white sandstone, which has been placed as a "cairn" on the summit of the pass, is a notable example of this ripple; other examples of rippled-marked rocks, covering surfaces of many square feet, are also exposed on the road between the pass and Inshin, in the slate series; marks which I take to be annelid or molluscan tracks may also be occasionally observed on some of these ripple-marked slabs.

It will be observed that the white quartzitic sandstones which occur high up in the Panjal series on the Margan pass, have a striking resemblance to part of the Kiol series which I have considered elsewhere (Rec. Geol. Surv. Ind., Vol. IX, p. 160) as being probably the top of the Panjal series in the outer hills; the limestone which underlies the sandstones in the latter region is not, however, represented on the Margan pass; it is not impossible that some of these

sandstones really belong to the carboniferous series like that of Eishmakām; in the absence of fossils, however, I have thought best to class them as silurian.

Reverting to our section, we find that at the village of Inshin the Wardwan river follows for a short distance on the course of an anticlinal axis in the Panjal slates, the rocks on the right bank of the river having a south-westerly dip, while those on the left bank have a north-easterly dip. Below Inshin the anticlinal axis, with a north-westerly strike, continues for a short distance along the course of the river, and then, leaving the river, bends down and gains a nearly north-and-south strike. Continuing our course below Inshin along the river, after leaving the anticlinal, we pass for a short distance across beds with an easterly dip; further down the river we cross a synclinal axis, the beds to the eastward of this axis having a nearly due westerly dip. As we proceed to the eastward the rocks, which at first consisted of bluish slates and slaty sandstones, become gradually more and more micaceous and metamorphosed, until we come upon an anticlinal axis of gneiss, with a north-and-south strike, about seven miles above Marú; the gneiss, with mica-schists and micaceous slates or shales, continues in a series of minor synclinals and anticlinals as far as Marú.

To the north of Inshin the Panjal series continues as far as the old fort of Bassman, where those rocks are again underlaid by gneiss.

It will be observed from the above that no hard-and-fast boundary can be drawn between the Panjal series on the one hand, and the underlying gneiss series on the other,—there being a gradual transition between the two. The boundary here and elsewhere between the two series is generally drawn nearest to the first band of gneiss; it will be noticed in the sequel that many thick masses of slaty rocks occur in various places within the gneissic area; in some cases it is extremely probable that these masses of slate should be referred to the Panjal series, they having attained their present position by faulting. In an outline survey, however, conducted in the hasty and imperfect manner in which that of this part of the Himalayas must of necessity be, it is impossible to map in all these outliers.

Returning for a moment to the ripple-marked rocks of Inshin, we may observe that these rocks, which, as we have seen, occur chiefly near the top of the Panjal series, must have been deposited in shallow water, and probably in a subsiding area.

Again taking up our section at the village of Marú, we find that the gneiss continues up the Farriabadi river, with a general northerly strike and westerly dip, for some eight or ten miles, beyond which point I was unable to continue my survey on account of the vast quantity of snow which then filled the valley; in all parts of the valley the pebbles in the stream consisted entirely of gneiss or very similar metamorphic rocks, and it seems to be most probable that the same gneissic rocks extend to the summits of the barren and almost inaccessible range from which the stream takes its course. I may, perhaps, here mention that several boiling and sulphurous springs occur about ten miles up the Farriabadi river, and also in several other places of this district.

The gneiss in the Marú district is either fine-grained or porphyritic; in either case indistinguishable in hand specimens from granite; it passes in places into mica-schist, micaceous shales, and even into little altered slate, which latter is

frequently found interstratified with it; in no case, either in this district, or in the rest of the country here treated of, were veins of granite found penetrating the gneiss.

Between the villages of Marú and Hanzá the strike of the rocks becomes first north-westerly, and lower down again almost due north, following in this respect very nearly the course of the Wardwan river; the rocks on both banks have a north-easterly or easterly dip, while an anticlinal axis runs near the summit of the ridge on the right bank. The prevailing rock at Marú is gneiss, while at Hanzá white and massive quartzite is the most common.

At the bend of the Wardwan river, near the village of Lopar the strike of the metamorphic rocks again becomes north-westerly with a low north-easterly dip; an anticlinal and a synclinal fold are crossed in the southerly-flowing portion of the Wardwan river below Lopar; below this synclinal there is a low north-easterly dip, which continues as far as the village of Krur; there is much contortion of the rocks at Lopar. Gneiss is the most prevalent rock in the series of this district, it is generally very massive and granitoid, and most especially at the village of Ekáli; below the latter village the gneiss is underlaid by whitish quartzites very like those before mentioned as occurring higher up at the village of Hanzá.

At the village of Krur we come upon an abrupt junction, apparently a faulted anticlinal axis, with a north-westerly direction; the rocks on the southern side of this faulted anticlinal have a south-westerly dip of about seventy degrees, and consist of black slates with a few felspathic grains, in striking contrast to the gneiss and quartzitic rocks on the north of the same axis; micaceous or black slaty beds continue from this fault to Kishtwar, but no distinct beds of gneiss occur in the rocks immediately to the south of this fault; though another ridge occurs near Mogalmaídán. I have accordingly taken the line of this fault, as the boundary between the crystalloid and the slate series, the latter of which will be shown subsequently to be the equivalent of the lower part of the Panjal series.

V.—SECTION FROM KISHTWAR TO LAHÚL.

We may now proceed to trace the rocks of which we have just been treating further up the Chináb valley into British Lahúl: at the town of Kishtwar itself the rocks are chiefly micaceous or black slates, without any bands of gneiss; an anticlinal axis with a north-westerly direction traverses these rocks a little to the north of the town.

In the sharp bend which the Chináb makes immediately above the town of Kishtwar, the river cuts directly across the strike of the strata; above this bend, however, the river flows towards the north-west, and consequently with the strike. In proceeding up the river from Kishtwar we first cross the above-mentioned anticlinal and subsequently a synclinal axis; the rocks are either micaceous or black slates with a few sandstones, either grey or whitish in color; as we advance further up the river the rocks become gradually more and more crystallised and metamorphosed; till at the village of Pias they are chiefly massive quartzites passing locally into gneiss; the lowest beds exposed in the ravines at and near this place are of gneiss. This gneiss corresponds to that of the Ward-

wan valley; and the boundary between the crystalline and slate series has consequently been drawn a little to the south of the last-mentioned village.

Near the village of Galha the river cuts obliquely across an anticlinal axis; this axis appears to be the continuation of the faulted anticlinal axis occurring on the Wardwan river at Krur, to which we have already referred; it does not, however, appear to be faulted here; the same anticlinal continues its course along the foot of the range to the south of the Chináb in an easterly direction, as far as the town of Atúli, where we shall again have occasion to refer to it.

Between Pias and Seri or Sereri, the rocks consist of granitoid gneiss, mica-schist, and micaceous slates; the lower parts of the tilted beds are frequently more altered than the upper parts of the same beds; at Seri itself the rocks are almost entirely granitoid gneiss: further up, at Jar, white quartzite is more common, and there are various kinds of rocks intermediate in character between these two; a boiling spring occurs a little above the last-mentioned village.

At the junction of the Bhútna with the Chináb river we find a great variety of metamorphic rocks, among which we may mention gneiss (fine-grained, porphyritic, or garnetiferous), mica-schist, micaceous slates, garnetiferous shales, quartzites, black slate, with crystals of felspar, gradually passing into gneiss, and little altered slates and shales.

The anticlinal axis which we have already referred to as traversing the range to the south of the Chináb, crosses the latter river at Atúli, and taking a north-easterly direction runs for some distance up the valley of the Bhútna river, where it appears gradually to die out. The strike of the rocks on the southern side of this anticlinal gradually changes, till at Atúli it becomes north-easterly, the dip being to the south-east: higher up the Bhútna river the strike again bends round to regain its normal north-westerly direction, the dip being to the north-east. The rocks on the western side of this anticlinal on the Bhútna maintain their north-westerly strike and north-easterly dip, up to the faulted anticlinal.

In addition to the evidence of faulting afforded by the different strike of the rocks on either side of the Bhútna anticlinal, we have further proof in the distinct mineralogical composition of the rocks on the two sides of the river. The rocks on the right bank of the Bhútna at Atúli are black slaty shales, highly impregnated with sulphur and iron; higher up the river these rocks are succeeded by garnetiferous schists and granitoid gneiss: as far up as the village of Machail the rocks are chiefly granitoid gneiss, which appears to extend up to the Umasi-la. The rocks on the left bank of the river at Atúli consist of micaceous schists and shales abounding in garnets, and of thick-bedded granitoid gneiss.

I myself have not crossed the Umasi-la into Zanskar, but I learn from Mr. Drew's notes that the gneiss rocks continue across the pass into Zanskar, as far as the village of Ayting, where they are overlaid by silurian slates, as has already been determined by Dr. Stoliczka. It seems, therefore, probable that the whole of the great snowy range separating the Chináb valley from Zanskar consists of one great core of gneiss.

I also learn from Mr. Drew's notes that a few bands of pure white crystalline limestone occur interstratified with the gneiss in certain parts of the valley of the Bhútna river.

Leaving now the Bhútna river and again continuing our course up the Chináb valley, we find, in consequence of the curving of the above-mentioned anticlinal, that the latter river above Atúli cuts at first almost directly across the strike of the strata, through beds of garnetiferous mica-schist, shales, and gneiss. At the village of Sol, however, the strike has regained its normal north-westerly direction, following nearly the course of the river, the dip on either side being to the north-east. A little to the westward of the village of Patralli, the strike once more becomes almost directly north and south, and consequently nearly at right angles to the course of the river; near this change of strike we cross firstly a synclinal, and then a curved anticlinal axis; the strike above the latter becoming a little to the north of west, with a southerly dip on both banks of the river, the same strike and dip continues as far as Kilar; the rocks consist chiefly of mica-schist, mica-ceous shale and granitoid gneiss with bands of slate; at the village of Darwas a rock much resembling coarse pegmatite occurs apparently interstratified with the gneiss; below the former there is a thick band of a white felspathic rock containing large trihedral prisms of tourmaline. Immediately to the south of Kilar there is a very thick band of granitoid gneiss; this gneiss is overlaid conformably by a newer series of bluish slates and sandstones, which we shall now trace for a considerable distance, and which contain no truly metamorphic rocks. These newer slaty rocks will henceforth be designated the "Pangi slate-group."

Following these Pangi slates up the Chináb river, we find that at Sauch the slates are thick-bedded with occasional bands of splintery greyish shales; the strike at the latter place has changed to the north-west, with a south-westerly dip. At Saor we cross a synclinal axis in nearly vertical slates, which again cuts the river higher up, to the westward of the village of Sheli; above Saor there are a considerable number of bands of blue and fawn-colored sandstones mingled with the slates which here are nearly black and thick-bedded, or flaggy. Taking a cross section through the same rocks to the south-west of Tindi, we find that there is a descending series with a north-easterly dip across the Drati pass, beyond which I presume we should again come upon the underlying metamorphic rocks. Between Tindi and Margraon the Pangi slates contain large quantities of iron ore, partly in the form of the magnetic oxide; sandstones and occasional bands of blue limestone alternate with the slates. Through the thick-bedded black slates at and near the village of Salgraon, there are scattered a vast number of imbedded blocks of granitoid gneiss, either angular or water-worn, and varying in size from less than an inch to upwards of three and a half feet in diameter. These gneiss blocks extend through a vertical rock-thickness of at least two thousand feet and also occur over a very wide horizontal area, being found, though in smaller numbers, in the same beds near the village of Saor, some ten miles lower down the river; by following the Salgraon beds towards the south-east the same blocks might probably be traced a considerable distance in that direction also.

The occurrence of these blocks of gneiss in the Pangi slates proves uncontestably that some portion at least of the older gneissic rocks must have been upheaved and undergoing denudation at the period of deposition of the slates, and that consequently such gneiss must have undergone its metamorphism previously to the deposition of the slates.

With regard to the transporting power which brought these gneiss blocks into their present position, there can, I think, be but little doubt that it was either ice or the roots of trees descending some old river. From the vast number of these blocks, together with the large area over which they extend and the great thickness of rock through which they occur, I am strongly inclined to think that the former agent must have been the transporting power, however improbable it may appear that ice should once have floated in a sea so near the tropics. We must, however, remember that there is a somewhat parallel case in the ice-worn boulders of the Talchir group in India itself. If the supposition as to the origin of these boulders, here put forward, be tenable, it is evident that the old gneissic land must have formed elevated mountains, and the temperature of the climate was sufficiently low to admit of glaciers descending to the sea-level and bearing away with them rock-masses. I may add that the nearest gneissic mass to the erratic block near Salgraon is about twenty miles distant, and that the outer portion of this gneiss is conformable with the slate series, and consequently could not have afforded the blocks.

Continuing our course up the Chináb, we cross the before-mentioned synclinal between Salgraon and Sheli; the north-westerly flowing reach of the river at Triloknath runs along an anticlinal axis, and we come across another synclinal some seven miles above the latter place. Beyond Triloknath the rocks have a south-westerly dip up to and beyond the village of Tandi, where the Chandra and Bagha rivers unite; the rocks have the same general composition in this area as below, though limestone becomes relatively more common.

Following up the Chandra river, we find that the rocks on the left bank, and further up on the right bank also, have a north-easterly dip; these rocks extend southwards to the north side of the Rotang range where they rest conformably on gneiss and other metamorphic rocks; limestones are here common in the series.

The superposition of these Pangi slates and limestones on the metamorphic rocks of Kúlú has been already noticed by the late Dr. Stolickza ("Geological Observations in Western Tibet," p. 340), who considered that the former were probably of silurian age.

Returning now to Tandi, we may trace the same group of slates up the Bagha river till they again rest on gneiss; this gneiss, according to Dr. Stolickza, commences at the village of Kangsir or Kangsar on the Bagha,¹ and extends as far as the village of Darcha or Daree, beyond which it is overlaid by undoubted silurian rocks. This gneiss on the Bhaga river Dr. Stolickza considers as being equivalent to his so-called "central gneiss."

We must return again for a moment to Triloknath, and from thence ascend the valley to the north of that place, thereby obtaining another cross section of the strata; a short distance up the valley the beds with a north-easterly dip cease, and we come on beds with a south-westerly dip; these beds, which consist of slates and sandstones, form a regular descending series up to the village of Tingrat, becoming gradually more and more micaceous; near the latter village we come upon

¹ By a mistake at line 7 from the top of page 341 of Dr. Stolickza's above-quoted paper, the word *Chandra* has been substituted for *Bagha*.

bands of gneiss in the slates and further up upon massive granitoid gneiss. The boundary between the Pangî slates and the gneiss must here be considered somewhat arbitrary: it is drawn near the first gneiss band.

To the south-eastward of Chirpat in the same valley there occurs a large irregular mass of granitoid gneiss which extends nearly to the missionary station of Kailing, on the Bagha river, although it does not anywhere touch that river: the exact relations of this mass of gneiss to the Pangî slates is a good deal concealed by permanent ice and snow; it appeared, however, to underlie them, and may doubtless be considered as an outlier of the same gneiss found in mass to the north-eastward.

From the above description it will be apparent that the Pangî slate group forms an irregular ellipsoidal mass resting on a basin of gneiss and other metamorphic rocks.

We have now traced the same series of gneiss and other metamorphic rocks down the Wardwan valley and along the southern side of the greater part of the snowy range which separates the valley of the Chináb from Zanskar, and we have already taken several cross sections in various parts of this range, by which we were led to conclude that the same gneiss extended to its summit, between Atúli and Zanskar; more to the east we find from Dr. Stoliczka's notes that on the Chandra, the gneissic rocks are not more than a few miles in width and are overlaid by presumably silurian slates.

It now remains to consider for a moment the rocks forming this Zanskar (or, as Dr. Stoliczka calls it, Baralatse) range, more to the north-west in the Súrú district. Now, at page 347 of "*Geological Observations in Western Tibet*" Dr. Stoliczka observes—

"The metamorphic rocks of the Baralatse range, south of Suroo (Súrú), extend to the north of this place with an unchanged mineralogical character up to the village Zangra. Here they carry a large proportion of hornblende, and overlie a mass of gneiss in a dome-shaped bedding. The gneiss, which is very well exposed near the old fort, Carpo-khar, consists of a great quantity of white quartz, orthoclase and muscovite; biotite being rather subordinate. On the northern side it is overlaid by a similar hornblendic schist, which gradually changes into talcose and chloritic schists, these being themselves followed towards the north by micaceous schists. From Sankoo to Saleskoot tough chloritic and quartzitic sandstones prevail, and to the north of the last-named place they are in contact with syenitic rocks."

From this it would appear that the Zanskar (Baralatse) range at this point consists of a core of gneiss, overlaid by less altered metamorphic rocks, and the latter again by the above-mentioned hornblendic rocks, which probably sweep round to the north of Súrú, and separate the metamorphic rocks from the possibly eruptive syenitic rocks to the north.

At page 348 of the same Memoir, Dr. Stoliczka, in speaking of the hornblendic rocks of Sankoo, considers these rocks to be silurians; at page 351 he again remarks that "the gneiss of the prolonged chain, south of Padam and Suroo (Súrú), is the same as the central gneiss, only devoid of the albite granite veins." In the map I have accordingly assumed that the whole of the metamorphic rock

occurring below the hornblendic silurians is the equivalent of the central gneiss of Darcha at the south-eastern end of the range, and the gneiss of Wardwan; the central axis of the range being pure gneiss and the outer parts less completely metamorphosed, precisely as we have found to be the case in the Chináb district; this identification will be again referred to.

I may also observe that I find from Mr. Drew's notes that the hornblendic rocks in the neighbourhood of Dras very much resemble some of the Kashmir amygdaloids, the probability being that those of Dras swing round between the northern extremity of the Súrú metamorphic rocks and the carboniferous rocks of the Zoji-la, to join the amygdaloidal silurians of Kashmir: it will, however, require a tour in that direction to settle this point. To the north of the Dras silurians we gather from Dr. Stoliczka that the syenitic rocks belong to an entirely different series from the gneissic rocks of the Zaskar range.

VI.—SECTION FROM KISHTWAR TO KASHMIR.

Returning once again to Kishtwar, we have to carry a section from thence into Kashmir, across the Marbal pass. This line of country has been already traversed by Dr. Stoliczka, who at page 350 of his often-quoted paper on Western Tibet dismisses the subject with the remarks that "to the east of the Marbal pass only metamorphic rocks have been observed all the way to Chamba;" and that "some of these altered rocks are probably altered silurians, but there is every reason to expect that still older formations may be found in them."

The Kishtwar and Kashmir section requires a somewhat fuller examination at our hands than the above, as from it alone are we able to connect the slates of Kishtwar and Pangi with the slates and amygdaloids of the Panjal series.

Between Kishtwar and Mogalmaidán the micaceous sandstones and black and greenish slates which we have seen to occur at the former place continue; the anticlinal axis which runs a little to the north of Kishtwar is continued near the road, and beyond Mogalmaidán its strike bends upwards to the north. The section at and beyond the latter place is somewhat obscured by forest, but it appears probable that the middle of this anticlinal is occupied by a ridge of granitoid gneiss overlaid by slates; to the south-west of Mogalmaidán, we have an ascending series of slates about halfway up to Khashimarg station; the second half of this section being occupied by a descending section of similar rocks, which rest on granitoid gneiss at Pipran station; the latter gneiss seems to be continuous with the gneiss which I have described in my paper on the Geology of the Pír Panjal as underlying the rocks of the Panjal series at Banihal. In the upper half of the slate series between Mogalmaidán and Khashimarg there occur numerous beds of the characteristic Pír Panjal amygdaloids and conglomerate.

Leaving the gneiss beyond Mogalmaidán on the Kashmir road, we pass over an ascending series of slates and amygdaloids, with bands of conglomerate for a considerable distance; an anticlinal axis passing through these rocks near Singpúr; these slates and amygdaloids belong to the typical Panjal series.

Beyond Singpúr we come upon a series of greenish slates and sandstones, with a north-easterly dip, in which about six miles to the east of the Marbal pass, I found a considerable number of specimens of *Productus*, *Spirifer*, and other car-

boniferous fossils. These rocks are the continuation of the carboniferous series of Kashmir. They appear to be faulted in between the rocks of the Panjal series, from which they are distinguished by the absence of the amygdaloids, so characteristic of the latter, by the slates being thin-bedded and banded, in place of thick-bedded, by the presence of beds of chert or limestone, and by their characteristic fossils, when the latter occur.

The beds with the north-easterly dip continue along the road till we get near to the Marbal pass, where we cross obliquely an anticlinal axis in nearly vertical carboniferous rocks; the same axis continuing into Kashmir and joining with the axis previously noticed as occurring to the south of Nowbûg. A small patch of carboniferous limestone occurs to the south-east of Ail station; and a bed of the same limestone is interstratified with the slates on the left of the road on the eastern side of the Marbal pass. The ridge on which Ail station is placed consists of rocks of the Panjal series, with a north-easterly dip.

On the Kashmir side of the Marbal pass the carboniferous rocks contain more cherty beds, in which fossils are extremely numerous; near Wankringi halting-ground there occurs a thick band of conglomerate in the same rocks; and some of the sandstones are ripple-marked. Below the last-named locality the Panjal rocks, with the same north-easterly dip, bend down to the southward; the Tansan stream forming the boundary between the two series, as far as the village of Wyl, where the carboniferous rocks strike obliquely across the ridge to the north-east of that place, beyond which we have already described them in the section from Kashmir to Wardwan.

The carboniferous rocks to the south of Wyl have a south-westerly dip; north of that village the dip is to the north-east; an anticlinal axis continuous with that before noticed near Sagam running along the ridge to the north of Wyl.

The Panjal rocks to the north-east of the Tansan river are composed almost exclusively of amygdaloids; the carboniferous rocks below Marbal are almost entirely limestones.

From the above it is evident that we must amend Dr. Stoliczka's statement, given at page 350 of his "Observations in Western Tibet," that the carboniferous rocks do not extend to the eastward of the Marbal pass (*i. e.*, if the word *pass* is used in its normal sense to signify the "crest"). The occurrence of limestone and carboniferous fossils six miles to the east is a sufficient proof of this error.

The slaty and sandy carboniferous rocks of the Marbal pass, abounding in fossils, seem to replace the limestones of the valley of Kashmir, and, as we have already seen, may probably be considered as the littoral deposits of the basin in which the limestones were laid down.

VII.—GENERAL CONCLUSIONS.

From a perusal of the facts detailed in the foregoing sections, and from the Memoirs of Dr. Stoliczka, Mr. Medlicott, and myself¹ on the rocks of different

¹Stoliczka: Mem. Geol. Surv. India, Vol. V.

Medlicott: Do. do. do. do., Vol. III.

Do. Rec. do. do. do., Vol. IX.

Do. Geology of Kumaon and Garhwal in Memoir on Hill Districts of N.-W. Provinces.

Lydekker: Rec. Geol. Surv. India, Vol. IX.

districts in the Himalaya, we may draw the following general conclusions as to the older Palæozoic rocks of our present area, *viz.* :—

That the Pír Panjal range consists of a series of silurian slates and amygdaloids resting on a core of gneiss.

That the same rocks are continued into Kishtwar, where they rest on the gneiss of the Zanskar ridge, and that they also have the same relations in the Wardwan valley.

That the same rocks extend to the eastward, where they rest on the gneiss of the Dhaoladhar range.

That the same rocks recur on the northern side of Kashmir, where they are overlaid by carboniferous and newer rocks.

That the gneissoid rocks of Súrú are continued down the Wardwan valley, extend to Pangi, and are *apparently* continuous with the “central” gneiss of the Bagha river.

That the Pangi slates have the same relationship to the gneiss of Pangi and Kúlú as have the silurian Panjals to the gneiss of Wardwan.

That the slaty rocks on the northern side of the Zanskar range have the same relation to the gneiss as have those on the south side, and that consequently if the gneiss of the two areas be of the same age, the overlying rocks will also be of the same age.

Our next point is to consider how these various rock-groups are to be connected together, and also as to what horizon in the geological series they belong.

Before proceeding further, it will be well to remind the reader that Dr. Stoliczka determined two distinct horizons of gneiss in the Himalaya; one of these kinds of gneiss is to be found on the right bank of the Indus in Ladák, and since it conformably underlies carboniferous rocks is supposed to represent altered silurian strata. The second kind of gneiss was named by Dr. Stoliczka “central gneiss,” and according to that author¹ “is overlaid by undoubted silurian rocks,” though we are not told whether the overlying rocks are conformable or unconformable to the gneiss. This “central gneiss” was at first supposed to be characterised by being traversed by veins of albite-granite, but as might have been supposed, this turned out to be a somewhat local character. It is not therefore apparent whether the “central gneiss” was supposed to have been gneiss at the time of the deposition of the silurian series or not; if, as I have suggested above, the gneiss blocks which occur in the Pangi slates were derived from the neighbourhood, it is evident that they must have been derived from gneissic rocks, which existed as such at the commencement of the deposition of the Panjals, and which, if the “central gneiss” really conformably underlies the silurians, must be older than the former.

Now, we have already seen that Dr. Stoliczka unhesitatingly recognised the gneiss of Darcha as being “central gneiss,” and also that he conjectured that the gneissic rocks of Súrú belonged to the same group, and it is quite clear that the latter underlie conformably the slate series, which we presume to be of silurian age; if this identification be valid, the “central gneiss” must also underlie the silurians conformably.

¹ Geological Observations in Western Tibet, p. 341.

Again, if this hypothesis be correct, the "central gneiss" will be the equivalent of some part of the gneissic series of the northern flanks of the Zaskar range, though it is, of course, quite possible that in those places where there is a transition from slate to gneiss that gneissose beds in one place may correspond to slaty beds in another.

On the other hand, the "central gneiss" is supposed to be the oldest known rock in the Indian Himalayas, and if we consider that this gneiss is the same as the gneiss which underlies conformably the silurian slate series, we should be driven to the conclusion that the gneiss from which the pebbles in the Pangl slates are derived was older than the "central gneiss."

The latter consideration would lead us to the conclusion that the "central gneiss" must be distinct from the gneiss underlying the Kashmir silurians, and that there is a break between the two, the Darcha gneiss really being unconformable to the overlying silurians, and a great portion of the gneiss of the Zaskar range being unconformable to the gneiss which underlies and alternates with the slate series, and being contemporaneous with the central gneiss. I cannot, however, say positively which of these two hypotheses is the correct one; and accordingly all the gneiss in our area has been colored of the same shade.

It seems evident that the gneiss which underlies the Pír Panjal slates is the same as that which underlies the slates of Kishtwar and the Wardwan, and also that which underlies the Pangl slates on the north of the Rotang pass, though we cannot say the same with regard to the gneiss of Darcha.

The gneiss of the Dhaoladhar, if we may judge from its abrupt termination to the north-west, may be the equivalent of the "central gneiss" of Darcha, although in strike it corresponds more nearly with that of the Panjal range.

If it should turn out that the central gneiss be older than the *infra*-silurian or Cambrian gneiss, it will be necessary that the centre of the mass of rocks forming the Zaskar range should be colored of a different tint from the gneiss of the rest of the map, with the exception probably of the granitic mass at Kailing and that of the Dhaoladhar range. Only an arbitrary boundary could, however, in any case be attempted.

It seems, therefore, to be apparent that all the gneiss in the area under discussion is older than the great mass of rocks of the silurian period (with the possible exception of a small mass in the Lower Sind valley), and that in certain instances there is a passage from the conformably overlying slates to the underlying gneiss, in which case the gneiss generally may be called Cambrian.¹ Further, there is evidence of the existence of another kind of gneiss, which existed as such at the silurian period; this gneiss occurs probably in the Zaskar range, but whether or no it is the same as the "central gneiss" we are at present unable to say.

With regard to the overlying rocks, we have seen that the Panjal series is *infra*-carboniferous, and we may therefore consider them (in the absence of any

¹ Everywhere this gneiss is overlaid by a great thickness of slates, which are considered as silurians; the conformable gneiss being always below this thickness is called for the sake of distinction Cambrian, though it may, of course, be occasionally in part silurian, or, on the other hand, part of the slates may sometimes be Cambrian.

fossil evidence) as being silurian; we have traced the same rocks into the Wardwan, and also into the Kishtwar country, and it is probably the same slate series which overlies the gneiss of the Dhaoladhar.

With regard to the slates and limestones of Pangi, we find that they rest upon gneissic rocks in the Kilar district, which gneissic rocks are almost certainly the same as those of the Pír Panjal, which, as we have seen, underlie conformably the silurian slate series; it is therefore probable that the Pangi series is also of silurian age. If, as we have suggested, the Darcha gneiss is older than the Kilar gneiss, there will be unconformability in the junction of the slate and gneiss in the one area, and conformability in the other, which would also lead to the inference that the Cambrian gneiss is totally unrepresented at Darcha, unless some of the lower slates be its equivalent.

The Pangi slates were considered by Dr. Stoliczka, to be in all probability the equivalents of the silurians of Lahúl which "overlie" the "central gneiss;" the silurians of Lahúl are continuous with those of the Padam valley, which, as far as I can gather, overlie Cambrian gneiss on the northern side of the Zanskar range, exactly as do the Pangi slates on the southern side. Although the absence of fossils from the latter group, as far as we know at present, may be considered by some as leaving the question open to doubt, the probability as to their silurian age is to my mind very strong indeed.

We have seen that the valley of Kashmir is bounded generally by interstratified trap and silurian slates, interrupted along the axis and to the north-west by carboniferous limestone, and more massive trappoid rocks; at the north-western end of the valley we have seen conclusively that the carboniferous rocks occupy a synclinal in the silurians and it is probable that they have the same relations at the Marbal pass to the south-east. This would lead us to infer that the axis of the valley of Kashmir lies along a synclinal; the normal relations of the rocks having, however, in several places, been much disturbed.

If we admit the foregoing references, the following table will approximately represent the chronological succession of the palæozoic strata in the area under consideration, as far as we are at present able to classify them:—

Slates of Marbal pass	} Carboniferous.
Limestones of Islamábád and Manasbal; slates and limestones of	...	...	...	...
Eishmakám and Lidar valley	...	...	...	...
Slates of Lahúl	} Silurian.
Slates and limestones of Pangi	...	...	...	...
Slates of Kishtwar	...	...	...	...
Slates and trappoid rocks of Pír Panjal	...	...	...	...
Trappoid rocks of Kashmir	...	...	...	...
Gneiss of Pír Panjal	} Cambrian.
Upper gneiss of Wardwan and Zanskar range	...	...	...	...
Kúlú gneiss	...	...	...	...
Central gneiss of Darcha	} <i>Infra</i> -silurian, but exact age not determined.
Lower gneiss of Wardwan and Zanskar range	...	...	...	...
Dhaoladhar gneiss	...	...	...	...

I must now say a few words as to certain relationships of some Himalayan rock-groups, which were suggested by Dr. Stoliczka, at page 141 of his "Memoir on the Rocks of the North-Western Himalaya."

It is there stated that the *infra*-Blini sandstones and Simla slates probably correspond with part of the Bhabeh group; if we refer to page 341 of the "Observations in Western Tibet" we find that the Lahúl silurians are also supposed to correspond with the Bhabeh group. The group of silurians in the above table may therefore also be probably referred to the Bhabeh group, with which they agree in overlying gneiss.

Referring again to page 141 of the "North-Western Himalaya," we find that the Blini group is conjecturally correlated with the Muth group; the one overlying the *infra*-Blini (Simla slates) and the other the Bhabeh group.

In the same memoir (page 141) a part at least of the *infra*-Krol group is conjectured to be the representative of the Kuling or carboniferous series, while the overlying Krol limestone is likewise conjecturally correlated with the Lilang or triassic series.

With the two latter correlations I may say at once that I cannot agree, and for the following reasons: firstly, I have already stated at page 161 of my "Memoir on the Geology of the Pír Panjal," my opinion that on account of their composition, position and relation to the older rocks, the Krol and Kiol groups are probably equivalent; secondly, the Kiol group occurs at the top of the silurian rocks (the series being inverted) precisely in the same manner as do the carboniferous rocks to the north of Kashmir; thirdly, the Kiol group agrees precisely in composition with the carboniferous rocks of the north of Kashmir: both groups consisting of massive blue limestone, polychroic slates and sandstones; fourthly, the rocks of the Kiol group are quite unlike the light-blue banded limestones, dolomites, and slates of the north of Kashmir; fifthly, no limestone occurs in the silurian rocks of Kashmir; there is, therefore, a fair presumption that the Kiol group does not belong to that period, while if we refer it to the triassic period, we have no rocks to represent the carboniferous period.

It is, I think, therefore extremely probable that the Kiol group may be of carboniferous age. This being so, and assuming the identity of the Krol with the Kiol group, the former also (and probably the *infra*-Krol group) will be of carboniferous age.

It may be well here to mention that in my above-quoted paper I considered the Kiol group as being probably partly of upper silurian and partly of carboniferous age; I was led to this inference from the fact, that in many parts of the valley of Kashmir itself the junction between the silurian rocks of the Pír Panjal and the carboniferous series is often a faulted one, and I was led from this to think that there was a break between the two which was filled by the lower Kiol beds; other sections, however, to the north of Kashmir, have shown the carboniferous limestones and slates resting conformably on the silurian Panjals, and have shown, as I have said, that the Kashmir silurians contain absolutely no limestone.¹

¹ At page 161 of my above-quoted paper, the Kiol series is compared to the Kuling series, as regards mineralogical composition; the latter group is there by an accident stated to be of triassic in place of carboniferous age; the similarity in composition of the two series adds some confirmation to the probability of the carboniferous age of the former; in line 14 of page 162 of the same memoir the word *Lilang* should be substituted for *Kuling*.

The assumption of the carboniferous age of the Kiol group leads to another modification of the views expressed in my previous memoir. It was there suggested that the great limestone inliers of the Jamú hills were the equivalent of the carboniferous limestone of Kashmir, and were consequently distinct from the Kiol and Krol groups.

I now, however, think it probable that the three groups belong to the same period; the greater prevalence of pure massive limestone in the Jamú hills than along the foot of the Pír Panjal is not greater than in the carboniferous rocks of the valley of Kashmir, over those of Eishmakám; while in one portion of the Kiol series, to the north of Púnc, the strata are almost entirely limestone.

The above propositions being accepted, it will be evident that the Blini series is represented in the upper part of the Panjal series, below the Kiol group.

According to the above views, the following table will represent the equivalent rock-groups in the Simla and Kashmir Himalaya. I wish it, however, to be most distinctly understood that, although the relationships *inter se* of the various rock-groups in the two areas are, with a few exceptions, pretty accurately determined, yet that the correlations of those of one area with those of the other can only be viewed in the light of a probable hypothesis, and not as a fixed fact.

Approximate classification of rock-groups in the Western Himalayas.

KASHMIR TERRITORIES AND LAHÚL.	EAST OF KASHMIR.	AGE.
α { Sandstones and slates of Zoji-la and Panjtarni. β { Upper limestones and dolomites of Amrnath, Sunamarg, Manasbal and Dras river.	Lilang series.	{ Rhætic and trias.
Limestones of West Kashmir. Blue limestones of Manasbal. Limestones and slates of Marbal pass, Lidar and Upper Sind valleys. Kiol series (?). Great limestone of Jamú hills (?).	{ Kuling series. Krol limestone (?). <i>infra</i> -Krol group (?).	{ Carboniferous.
Upper Panjal slates, shales and trap-poid rocks. Trappoid rocks of Wular lake.	{ Math series. Blini series.	{ Upper silurian.
Lower Panjal slates; lower slates and trappoid rocks of Kashmir. Slates and limestones of Pangl. Lahúl slates.	{ Bhabeh series. <i>infra</i> -Blini, or Simla slates	{ Lower silurian and Cambrian (?).
Gneiss of Pír Panjal. Upper gneiss of Wardwan and Zaskar range. Kúlú gneiss.	{ ? ?	{ Cambrian.
Central gneiss of Darcha. Lower gneiss of Wardwan and Zaskar range. Dhaoladhar gneiss.	{ Gneiss of Chor mountain	{ <i>Infra</i> -silurian, but exact age not determined.

It will be seen that in this rough and approximate table a gap occurs in the second column between the lower slates and the "central gneiss," which cannot be filled up until the relations of the two in the matter of conformity or unconformity are settled; if they are unconformable, and the "central gneiss" is older than the Pír Panjal gneiss, it may then not be improbable that some part of the Simla slates may be the equivalent of the Pír Panjal gneiss.

Since the above was written I have seen the able paper of Colonel McMahon on the Simla Himalayas.¹ The author is there of opinion that the Simla slates and other non-crystalline series are certainly newer than the crystalline series; he also thinks that the hypothesis of inversion will not explain the case, but that there was an original unconformity between the two series; the slates having been deposited on a denuded surface of gneiss. In the Pír Panjal and in Pangl, I think the latter explanation cannot be adopted, as there is a passage between the crystalline and non-crystalline series. If original unconformity exists in the Simla region, it would tend to confirm my suggestion that there exists gneiss belonging to two periods in these regions; the Simla or "central" gneiss being older and unconformable to the slates, while the gneiss of the Pír Panjal is conformable to the slates, and has been metamorphosed out of their lower beds, and may consequently be in part the equivalent of the lower Simla slates.

It will require another season's work to trace the relations of the triassic rocks of the Zoji-la to the gneiss of Súrú and the Zanskar range, and also, as I have previously said, to trace the former rocks in the opposite direction into the Tilail or Kishenganga valley.

NOTICES OF SIWALIK MAMMALS, BY R. LYDEKKER, B.A., *Geological Survey of India.*

The Indian Museum has again been enriched by a large collection of vertebrate fossil remains obtained from the Siwalik series of Sind and the Punjáb, by Messrs. Blanford, Fedden, and Theobald, and their native assistants. Many of these fossils are, of course, merely duplicates of previously acquired specimens, while others belong either to new genera or species, or illustrate more fully other species whose existence has hitherto been only slightly indicated to us by the evidence of a few fragments of bone, or isolated teeth.

In the present paper I shall shortly notice a considerable number of the more interesting of these specimens, reserving for a future opportunity the figuring, and more detailed description, of the specimens, in the hope that I may then have still more materials to work upon.

Before proceeding further, it may be well to notice certain conclusions which I have lately arrived at respecting the distribution in time of some of the fossils.

It may, I think, be now stated with considerable probability, that, as I have hinted before, the mammaliferous beds of Sind belong to a somewhat lower horizon than that which yields the majority of the fossils in other areas. These mammaliferous Sind beds (Manchhar) overlie the Gáj beds, which seem to be upper miocene, and cannot therefore be much older than the lower pliocene, or

¹ Rec. Geol. Surv. Ind., Vol. X, p. 204.





the very highest of the miocene. Their mammalian fauna is nearest to that of the miocene of Europe, and does not contain, as far as we know, any of the modern forms which occur in the Siwaliks of the Punjáb, which may probably be considered to be higher up in the older pliocene. The occurrence of a large number of mammalian genera which are confined to the miocene in Europe, in the pliocene of India, is paralleled by what occurs according to Professor Marsh in North America, where European miocene mammals occur in the older pliocene.¹

The mammalian tertiary fauna of Sind is characterized most especially by the presence of great numbers of both bunodont and selenodont pig-like animals, the majority of which are, however, unfortunately only known to us (with the exception of those genera which also occur in Europe) by isolated teeth.

These same Siwalik or Manchhar beds also contain the remains of *Dinotherium* in considerable abundance; in India this genus is elsewhere known only from Kach, Kúshalghar, and Perim Island, from beds which are probably low in the Siwalik series. In the Sind area *Mastodon* and *Hippotherium* are common, and two teeth of the miocene genus *Amphicyon* have also been found there.

Of the modern and existing genera *Euelephas*, *Equus*, *Bos*, *Bubalus*, *Capra*, and *Hippopotamus*, which are so characteristic of the typical upper Siwaliks, I am not aware that any remains have been obtained from the Manchhar beds. The only two living genera of Mammals of which we have clear evidence as occurring in these beds are *Rhinoceros* and *Sus*, both of which have existed since the miocene epoch.

From the still older marine Gáj beds, Mr. Fedden has this year obtained a part of a skull and three upper molars of *Rhinoceros sivalensis*; the specimen was obtained at a considerable distance below the Manchhar horizon, but its precise position, Mr. Fedden tells me, could not be defined, owing to the irregularity of the thickness of the beds in different localities and the absence of the Manchhars at this spot. This *Rhinoceros* is thus proved to have been one of the earliest of the Siwalik Mammals, having lived in the Gáj period.

In the Siwaliks of the Punjáb Mr. Theobald seems to have proved pretty clearly from the sections sent down with the fossils, that in this region the greater number of extinct genera do occur in the lower beds of the series, while the greater number of living genera occur higher up; this idea cannot, however, be thoroughly worked out, owing to the fact that the fossils occurring in one bed are washed out and mingled with those from another. I imagine that this confusion is especially the case with the very few fossils which occur below the great fossiliferous zone, as they are generally picked up by native collectors and mixed with those from other zones. The lower beds, like those of Núrpur and Kúshalghar from which *Amphicyon* and *Dinotherium* have been obtained, are very probably the equivalents of the Manchhars.

Hitherto all, or nearly all, the Siwalik fossils seem to have been found as isolated bones; during the past season, however, Mr. Theobald has discovered a bed at Nikí in the Punjáb, where a vast number of associated bones of many

¹ Address to American Science Institution, New-Haven, 1877, p. 24.

species are found mixed *pell-mell* together; and which probably indicates an old quicksand in which the Siwalik animals were engulfed.

From this deposit I hope that many valuable specimens will yet be obtained, which will throw more light on the affinity of some of the less known Siwalik animals than can be obtained from the study of a few isolated bones or teeth. The bed has already yielded many specimens, among which I may notice the complete cranium of a gigantic pig, part of the cranium with milk dentition of the new trilophodont *Mastodon* and several associated sets of foot bones. Among the latter is a nearly perfect foot of *Hippotherium*, which shews us that the Asiatic species of the genus had precisely the same conformation as the European forms.

I will now mention the most important and interesting of the specimens obtained during the past year; in the course of these notices I shall have to mention several re-determinations of previously noticed specimens; these re-determinations have either become necessary owing to the discovery of more perfect specimens or owing to the errors of previous determinations.

These re-determinations, though of course to be regretted, are almost unavoidable in determining such isolated specimens as are the majority of the fossils from the Siwaliks, and are also made more frequent in the present instance, owing to the extremely unsatisfactory state of the previous literature referring to Siwalik Mammalia.

I may also here mention that Mr. Theobald has collected several bones of Siwalik Birds, and a considerable number of the remains of Reptiles; these, however, will not be further noticed at present, as I have not yet had an opportunity of studying these in any detail.

PRIMATES.

Genus: MACACUS.

Remains of quadrumanous Mammals have been long known from the Siwaliks, and indeed the specimens obtained from those rocks were the first known fossils belonging to the order. These remains, however, are of extremely rare occurrence, the known specimens only numbering some five or six; up to the present time, no specimens of the remains of this order have been obtained among the many hundreds of specimens which Mr. Theobald has forwarded from the Siwaliks of the Punjáb to the Indian Museum. In December last, however, two specimens of the upper jaw of a small monkey were received at the Indian Museum from Mr. Theobald, which had been obtained from the Siwaliks of the village of Asnot, in the Punjáb, and which form the subject of the present notice.

Before describing the new specimens, it may be well to consider for a moment the remains of Monkeys which have been previously obtained from the Siwaliks; the memoirs on the specimens will be found collected in the first volume of the "Palæontological Memoirs," accompanied by a plate.

The first specimen discovered was a part of the right maxilla with the molar series. In speaking of the specimen the discoverers (Messrs. Baker and Durand) conclude by observing: "This circumstance and the differences before pointed out,

clearly separate the fossil from the species belonging to the genera *Cynocephalus* or *Semnopithecus*.”—(“Palæontological Memoirs,” Vol. I, p. 299.) The authors seem here clearly to have considered that the species could not belong to *Semnopithecus*, and not to have assigned it to any genus. The next notice of the specimen occurs at page 7 of Professor Owen’s “British Fossil Mammals and Birds,” where the following passage occurs: “All these remains were entirely fossilised, and they satisfactorily confirmed the conclusions of Lieutenants Baker and Durand, that a large species of *Semnopithecus* had co-existed with the *Sivatherium* and the *Hippopotamus*.” Now, as we have seen, the authors in question, if I understand them aright, expressly stated the distinctness, in their opinion, of the species from *Semnopithecus*.

Apparently from this statement of Prof. Owen, H. von Meyer in the “Index Palæontologicus” (Nomenclature, Vol. II, p. 1133) refers to this specimen unhesitatingly under the genus *Semnopithecus*, and there gives it the name of *S. subhimalayanus*.

In his “Osteographie” (Primates, p. 60) M. de Blainville refers to the specimen, and thinks (if indeed it belong to a Monkey at all) that it is more nearly allied to *Mucacus*, and, above all, to *Cynocephalus*, from both of which genera the original describers thought that it was generically distinct, although they observe that “were it not for the size of the canine and the fifth molar, it presents some resemblance to the genus *Mucacus*.”

From the above it seems to be clear that the specimen in question has no right to the generic title of *Semnopithecus*, though I do not mean to say that it may not belong to it. When the specimen is alluded to under that name, it must be distinctly understood that this is only done as a matter of convenience, and because it has so frequently been referred to under that name.

The next specimen was an astragalus discovered and described by Messrs. Falconer and Cautley, who remark (“Palæontological Memoirs,” Vol. I, p. 300): “It (the specimen) corresponds exactly in size with the astragalus of the *Semnopithecus entellus*,” and again: “This astragalus, in conjunction with Messrs. Baker and Durand’s specimen, satisfied us of the existence of at least two distinct fossil *Quadrumana* in the Siwalik hills.”

In the same Memoir these authors also treat of two other specimens which were both fragments of lower jaws containing teeth; one of these jaws was larger than that of *S. entellus*, and belonged, according to Falconer, to “a species of smaller size than the animal to which the specimen described by Messrs. Baker and Durand” belonged; there is no direct statement of the genus of the specimen, though I infer that the authors inclined to think it belonged to *Semnopithecus*. It appears to me to be not improbable that this specimen and the above-mentioned Astragalus may have belonged to the same species.

The other specimen of a lower jaw belonged to an animal intermediate in size between *Semnopithecus entellus* and *Mucacus rhesus*; this specimen the authors thought probably belonged to the genus *Mucacus* (*Pithecus*); an additional specimen of the lower jaw of the same species was also obtained.

There are therefore three Siwalik species of Monkeys known from the evidence of molar teeth, viz., a large species specifically named *subhimalayanus*, and which

is often noticed as a *Semnopithecus*, an intermediate species probably belonging to that genus; and a small species probably belonging to *Macacus*. There seems also to be evidence of another species known from a single upper canine, but this does not concern us at present.

We may now return to Mr. Theobald's specimens; the first of these consists of a portion of the right maxilla, containing the three true molars and the alveoli of the two premolars; the two first molars are slightly touched by wear, while the last ("wisdom tooth") is still in germ, being very late in its time of protrusion. The crowns of the teeth are oblong in shape, and bear on their masticating surfaces four cones placed at the angles of this surface; at either end there is a slight transverse talon-ridge. The first molar is smaller than the second, and the third nearly equals the first, and is somewhat narrowed posteriorly.

The second specimen is an almost similar portion of the left maxilla of a somewhat older, though similarly sized, animal; it shews the anterior root of the zygomatic arch, the last true molar, and the alveoli and fangs of the last premolar and two first molars; each of these teeth was inserted by three fangs. The last tooth of this specimen is exactly like the same tooth of the previous specimen, and shews that both specimens belonged to the same species. The anterior root of the zygoma is placed immediately above the interval between the alveoli of the first and second molars. In the following table the dimensions of the first of Mr. Theobald's specimens are given in the first column (*a*), the corresponding dimensions of *Macacus (Inuus) rhesus* in the second column (*b*), and those of *Semnopithecus entellus* in the third column (*c*):—

	<i>a.</i>	<i>b.</i>	<i>c.</i>
Length of three molars	0.75	0.66	1.0
" first molar	0.26	0.29	0.32
Width of " "	0.22	0.28	0.30
Length of second "	0.29	0.31	0.35
Width of " "	0.28	0.30	0.36
Length of third "	0.26	0.29	0.35
Width of " "	0.23	0.28	0.35

We have now to consider the question of the genus of the fossil specimens, which we shall find a by no means easy problem, as the teeth of allied genera of Monkeys are so excessively alike one another. *Firstly*, we may say that, from their squared crowns, the teeth in question do not belong to the genus *Hylobates*, in which the molars have rounded angles; *secondly*, that they do not belong to *Cynocephalus*, on account of their small size, and from the last molar being narrowed posteriorly, whereas it is of equal width throughout in the latter genus; *thirdly*, that they do not belong to the genus *Mesopithecus*¹ from the upper miocene of Attica, since the penultimate upper molar of that genus has an accessory tubercle on its external surface, which is wanting in Mr. Theobald's specimens; and, *fourthly*, that they resemble the teeth of *Cercopithecus*, *Semnopithecus*, and *Macacus* (including sub-genera) so closely that they must belong to one of these three genera.

Gaudry: "Animaux Fossiles de l'Attique," pl. I, figs. 6, 7.

The next question, therefore, is to find some character which distinguishes the molars of the three last-named genera. Now, if we turn to page 442 of Owen's "Odontography," we shall find that in treating of the molars of the mandrils, the author observes that the true molars "progressively increase in size from the first to the third;" and on the next page, that "the smaller Baboons, of the genus *Macacus*, repeat on a smaller scale the dental characters of the mandrils." Now, with all due deference to the author of the valuable work under notice, it does not appear to me that the characters given above are always characteristic of the genus *Macacus*, because if we refer to the table of measurements given above (and several specimens have been compared), we shall find that in *M. rhesus* the first molar is smaller than the second, which agrees with Professor Owen's statement, but that the third is smaller than the second, which does not.

In treating of *Semnopithecus*, Professor Owen remarks on page 443 that "the first molar is equal to the second." Now, in the table given above, it will be seen that in *S. entellus* the first molar is smaller than the second; and in the figured specimen of the dentition of this genus given in figure 5, plate 116, of the "Odontography," the first molar is also somewhat smaller than the second.

These characters do not, therefore, seem to be of any great value as affording means of distinguishing between the genera in question.

It does, however, appear that in *Semnopithecus* there is a tendency for the molars to be of more equal size than in *Macacus*, in which the first is always small and the second large; thus in *S. phayrei* and *S. siamensis* the first and second molars are of equal length; while in *S. entellus* and *S. cephalopterus* the second and third are of equal length, and the first slightly smaller. I have seen no instance in the genus *Semnopithecus* in which in the same jaw the first molar is smaller than the second, and the second larger than the third.

In the genus *Cercopithecus* there appears to be great equality in the size of the upper molars; thus in *C. sabæus* the three are of equal length; in *C. pluto* the two first are equal, and the third slightly smaller; and indeed in all the specimens that I have seen the two first are of equal length.

It is therefore apparent that the fossil specimens cannot belong to *Cercopithecus*; and it is also apparent that in the relative length of the molars they do not agree with any species of *Semnopithecus*, but that they do agree with *Macacus rhesus*; the evidence then so far is, that the fossils belong to the latter genus.

Now, with regard to the form of the teeth: in *Semnopithecus* and *Macacus*, the two first upper molars appear to me to be absolutely indistinguishable in the two genera: the last molar of *Macacus*, however, has the posterior talon-ridge forming a complete semicircle, which connects the two posterior cones of this tooth; in the corresponding tooth of *Semnopithecus*, on the other hand, this talon-ridge starts from the postero-internal cone, and curves upwards and outwards, to the base of the outer side of the crown, its curve forming only a quarter in place of half a circle, and not being connected with the outer cone at all. The last molars of the fossil specimens agree with the last molar of *Macacus* in this respect, and there seems, therefore, to be no doubt from this and the previous evidence that the specimens really belong to that genus.

Next, with regard to the question of species: the teeth are smaller than those of *M. silenus*, *M. rhesus*, and *M. radiatus*, and judging from the relative size of *M. radiatus* and *M. pelops*, the teeth of the latter would also be larger than those of the present specimens; again, in *M. rhesus* and in all other living species of the genus which I have seen, the anterior root of the zygoma is placed always behind the interval between the first and second molars, whereas in the fossil specimens, this root is exactly over this interval.

I have not been able to compare the fossil specimens with the teeth of other living species of *Macacus*; but as the former differ from the Indian species of the genus, and as all known Siwalik species of Mammals are extinct, the presumption is that the present specimens also belong to an extinct species.

Turning now to the fossil species of *Macacus*, we find that the following have been described; the small lower jaws described by Falconer from the Siwaliks and referred to above; a lower jaw from the London clay described by Professor Owen under the name of *Macacus eocenus*;¹ a portion of an upper jaw from the newer pliocene of Grays described by Professor Owen as *M. pliocenus*;² and a lower jaw from the pliocene of Montpellier described by Professor Gervais under the name of *M. priscus*.³

The small lower jaws from the Siwaliks described by Falconer belonged to an animal larger than *M. rhesus*, while Mr. Theobald's specimens belonged to an animal smaller than *M. rhesus*; now, since Falconer obtained two specimens of the lower jaw which agreed exactly in size, and since Mr. Theobald has also obtained two specimens of the smaller upper jaw, which also agree exactly in size, it seems to be probable that the latter belong to a different species from the former. The jaw on which *Macacus eocenus* of Owen was founded has been subsequently referred to *Hyracotherium*.⁴

Both *M. pliocenus* and *M. priscus* are too large to have belonged to so small an animal as that to which Mr. Theobald's specimens belonged.

It is therefore clear that the latter teeth do not belong to any named fossil species, and there is every probability that they do not belong to any living species: this being so, I shall propose to call the species *M. sivalensis*.

PROBOSCIDIA.

Genus: *MASTODON*.

I have already said in the Introduction that an adolescent cranium of the new Siwalik Trilophodont *Mastodon*⁵ has been found in the Potwar; this cranium contains the two last upper milk-molars and the first true molar; a detached second upper true molar of the same species has also been obtained from the Siwaliks; and several detached teeth from Sind. These specimens appear to prove the specific distinctness of *Mastodon falconeri*.

¹ Brit. Foss. Mam. and Birds, p. 1.

² Zoologie et Paléontologie Françaises, p. 11.

³ *Sup. cit.* Int., p. xlv.

⁴ Nicholson's Palæontology, p. 466.

⁵ Rec. Geol. Surv. India, Vol. X, p. 83.

Mastodon perimensis, Falc.

This species of Indian *Mastodon* has hitherto only been known from the mammaliferous beds of Perim Island in the Gulf of Cambay.¹ Among the specimens of *Mastodon* teeth in Mr. Theobald's Siwalik collection from the Punjab there is one complete lower jaw, and several detached molars which must be referred to this species and which prove its range into that region. The molars of *M. perimensis* are at once distinguished from those of *M. latidens* by the transverse valleys being greatly blocked by tubercles, by the ridges being higher, and by there being a slight alternation in the arrangement of the inner and outer columns of the latter. The same teeth are distinguished from those of *M. sivalensis* by the number of ridges being less, and by the ridges being less alternately disposed, and the valleys being in consequence more nearly transverse. Among Mr. Theobald's specimens are a first and a second upper true molar which are more complete than any specimens represented in the "Fauna Antiqua Sivalensis;" of one of these specimens I shall hope to give a figure on a future occasion.

Some fragmentary *Mastodon* molars from Sind collected by Mr. Blanford, belong, I think, to this species.

The lower jaw belonged to a completely adult animal, and contains the two ultimate molars; the first of these teeth is imperfect; the second is, however, complete, and contains five transverse ridges and a talon, according to the normal tetralophodont formula.

This jaw agrees with the lower jaws of other *Mastodons* and differs from those of elephants, in that the summit of the coronoid process extends upwards as high as the condyle; the coronoid and condyle are, however, more closely approximated than in other species of the genus. The inferior and posterior borders of the jaw are nearly at right angles to each other, the angle being rounded off.

The symphysis of the mandible is produced into an elongated spout, extending more than a foot in advance of the first molar; the symphysis is three inches longer than the last molar. This specimen does not exhibit any traces of incisors; but another specimen of the symphysis of the same species, also collected by Mr. Theobald, shews a small cavity on the left side of the extremity, which is quite likely to be a semi-obliterated dental alveolus. It is therefore quite possible that this species with a spatulate mandible may have been furnished with incisors, which were shed before the animal became adult. If this be so, the species would agree in character with the European *Mastodon longirostris*, which also has a spatulate mandible and lower incisors.

The most important measurements of this specimen are as follows:—

Length from hinder border of last molar to distal extremity of symphysis	29·0
" " anterior border of penultimate molar to " "	13·5
" of last molar	10·7
Interval between condyle and coronoid process	5·0

Mastodon latidens.

In this species, I have lately discovered that the last milk-molar of the upper jaw was displaced vertically by a simpler premolar, which was not previously

¹ Falconer's Palæontological Memoirs, Vol. II, p. 15.

known to have been the case. The specimen from which this interesting discovery was made consists of a portion of a left maxilla containing a single tooth in use which carries four ridges and which measures $3\frac{3}{4}$ inches in length. Above the base of this tooth the broken jaw shews a complete germ of a premolar, which I have removed from its matrix: the germ is oval in shape, and carries only two ridges, and fore-and-aft talons. Since the larger tooth is situated below a premolar, it is clear that the former is a milk-molar, and since it carries four ridges, that it is the last or third tooth of that series. I cannot, of course, say whether the penultimate milk-molar of *M. latidens* was succeeded by a premolar, but not unprobably such was also the case.

Genus: STEGODON.

Stegodon cliftii.

This species was originally named upon the evidence of teeth obtained solely from Ava and Burma, and I cannot find more than one recorded instance of its having been obtained beyond those countries. This instance occurs in the catalogue of the fossil vertebrata of the Asiatic Society of Bengal,¹ where a portion of a mandible of *S. cliftii* (No. $\frac{8}{64}$) is stated to have been obtained from the Siwaliks. In the table of the species of *Mustodon* and *Elephant* given on page 14 of the second volume of the "Palæontological Memoirs," the distribution of this species, like that of *Mustodon latidens*, is given as "Southern India and Ava;" now, the latter species is well known as occurring in the Siwaliks, and "Southern India" may be a misprint for Siwaliks; on the other hand, Southern India is given as the locality of *M. pandionis* which was obtained from the Deccan, and it is possible that *M. latidens* and *S. cliftii* have also been obtained from the Deccan: if so, however, all record of this has been lost; on this supposition the word "Siwaliks" is omitted from the distribution of *M. latidens*. All the specimens of *S. cliftii* figured in the "Fauna Antiqua Sivalensis" of which the locality is given, were obtained from Ava and Burma, and therefore the only recorded instance of the species occurring in the Siwaliks is the above-mentioned lower jaw.

The distribution of this species being so uncertain, it is a matter of some interest that I am now able to state clearly that the species does occur in the Siwaliks. I am not aware that any specimens of *Stegodon cliftii* have hitherto been recorded as having been found in the Sub-Himalayan Siwaliks.

Two specimens of molars of a *Stegodon* sent by Mr. Theobald seem undoubtedly to belong to this species: the first specimen is a portion of the (probably) first upper true molar; it carries five complete transverse ridges, a sixth having been broken away. In the number of ridges the tooth agrees with the first molar of *S. cliftii*; it differs from the corresponding tooth of *S. insignis* by having six, in place of seven ridges, and by being wider, and by the more open valleys: it is also much wider, and the valleys are more open than in the tooth which I refer below to *S. bombifrons*, though that tooth also contains six ridges. The second specimen is a right ramus of the mandible containing the ultimate true molar: this tooth agrees in general character with the corresponding tooth of *S. cliftii* represented

¹ Palæontological Memoirs, Vol. I, p. 113. — Cat. Foss. Vert. Mus. A. S. B., p. 75.

in fig. 5, Plate XXX, of the "Fauna Antiqua Sivalensis;" the latter, however, carries eight, in place of seven ridges, the number of ridges frequently varying by one or more in this tooth. The last lower molar of *S. insignis* carries from 11 to 13 ridges, and that of *S. bombifrons* 9 ridges; the latter tooth is further distinguished from the last lower molar of *S. cliftii* by carrying a large number of cusps on the ridges, whereas there are only four or five on the last lower molar of *S. cliftii*. The ridge formula of the true molars of *S. cliftii* will therefore now be as follows:—

$$\begin{array}{l} 6+6+8 \\ 6+6+(7-8) \end{array}$$

Stegodon bombifrons and *S. sinensis*.

A considerable number of molar teeth of other species of *Stegodon* have lately been collected by Mr. Theobald, among which there are some which call for a short notice here; most of these teeth belong to the "intermediate molars." It may be well to state here that the whole of the ridge formula of the molars of *S. insignis* has been determined by Dr. Falconer ("Palæontological Memoirs," Vol. II, p. 86) and is as follows:—

$$\begin{array}{ll} \text{Milk-molars.} & \text{Molars.} \\ \frac{2+(5-6)+7}{2+5+7} & \frac{7+8+(10-11)}{7+(8-9)+(11-13)}^1 \end{array}$$

The ridge formula of *S. ganesa* is considered by Falconer to be the same: the whole ridge-formula of *S. bombifrons* is not known, but it will be gathered from the figures in the F. A. S. that it is lower than in *S. insignis*; the third milk-molar has six ridges. (F. A. S., Pl. XXIX A, fig. 1.) Of *Stegodon cliftii* the ridge-formula of the anterior teeth is not known; the two first true molars, however, carry each six ridges, and I have already given their formula.

Having premised this much, our comparisons will be the more easily made. The first among Mr. Theobald's specimens to which I wish to call attention is a portion of a maxilla, containing the last milk-molar, and the first true molar, the latter tooth I shall often refer to as *a*; the former tooth appears to have carried six ridges, but is much worn; the latter carries six ridges, and fore-and-aft talons, the former joining the first true ridge in the middle; there is a slight tendency to a median division in the ridges, especially the anterior ones; each ridge carries fourteen or fifteen tubercles, and the four last ridges are much curved. The dimension of these teeth are as follows:—

Length of third milk-molar	.	.	.	.	.	4.1
Width of " "	.	.	.	.	.	2.3
Length of first true molar	.	.	.	.	.	5.9
Width of " "	.	.	.	.	.	3.0
Interval between 3rd and 4th ridges of first true molar	.	.	.	.	.	1.0

Now, it is quite clear, from the number of ridges carried by the first true molar, that these teeth cannot belong to *S. insignis* or *S. ganesa*; the first molar agrees with the homologous tooth of *S. cliftii* in carrying side ridges, but differs in form

¹ The ridges of milk-molar 2 are given as 5, in the specimen represented in F. A. S., Pl. XIX., fig. 1.

and relative size. The dimensions of the first upper true molar of *S. cliftii* represented in figure 2 of Plate XXX of the F. A. S. are as follows :

Length	6.1
Width	3.3
Interval between 3rd and 4th ridges	1.2

The new tooth is, therefore, relatively narrower, and is further distinguished by having a large hind talon which is wanting in *S. cliftii*. Of Falconer's species of *Stegodon* there therefore only remains *S. bombifrons* to which our specimens can belong; as the third molar of this species has six ridges, the first true molar should also have six ridges, and at first I thought of referring the teeth under discussion to *S. bombifrons* had it not been for certain reasons to be immediately noticed.

The true molar in this jaw agrees with the second milk-molar of a *Stegodon* from China, referred by Professor Owen¹ to a new species under the name of *S. sinensis*, in the following characters; both these teeth have curved transverse ridges, which carry from fourteen to fifteen tubercles, and have a slight median division of the ridges. In both teeth there is an imperfect ridge at the anterior end, which joins the middle of the first complete ridge: this imperfect ridge I consider to be only a talon, though Professor Owen regards it as the first true ridge. From a comparison of the Chinese and Siwalik specimens, I have not the slightest doubt but that they belong to the same species; the length of the Chinese second milk-molar is 2.9 inches and its width 2.0 inches: dimensions which would well correspond to those of the tooth which should precede the third milk-molar in the Siwalik specimen.

We have now to consider another first upper molar of a *Stegodon* from the Punjab which I will designate as *b*; this tooth carries only six ridges, and cannot therefore belong to *S. insignis* or *S. ganesa*. These ridges are very closely approximated and run straight across the tooth; there is a large hind talon. The length of this tooth is 4.9 inches, its width 2.9 inches, and the distance between the third and fourth ridges 0.8 inch. From these dimensions it will be quite apparent that this tooth is not the first true molar of *S. cliftii*, nor of the Chinese species. It at one time occurred to me that this tooth might be the third milk-molar of *S. cliftii*, but the approximation of the ridges is against that view. Again, the length of the worn third milk-molar of that species represented in figure 1 of Plate XXX of the F. A. S. is only 3.3 inches and its width 2 inches; it is therefore clear that tooth *b* does not belong to *S. cliftii*.

Now, with regard to *S. bombifrons*, tooth *b* agrees with the hinder molars of that species, in having broad and blunt ridges, ("Palæontological Memoirs," Vol. I, p. 81,) in having a hind talon, and having fewer ridges than the first molar of *S. insignis*. There is, therefore, every presumption of this tooth being the first true molar of *S. bombifrons*.

This being so, the first molar *a* and the Chinese tooth cannot belong to *S. bombifrons*, and since they do not belong to any other of Falconer's Siwalik species, we must retain for these Owen's name of *S. sinensis*.

¹ Quar. Journ. Geol. Soc. Lond., Vol. XXVI. p. 417, pl. 27.

One other tooth remains to be mentioned: this specimen is a small upper molar of a *Stegodon*, which from its carrying four ridges only, and from its size, must be a second milk-molar; the length of this tooth is 2·2 inches, and its width 1·4 inch. It cannot belong to *S. insignis* and *S. ganesa*, since the second milk-molar of those species has five or six ridges (F. A. S., Plate XIX, fig. 1); neither can it belong to *S. sinensis*, since it is much smaller than the homologous tooth of that species figured by Professor Owen, and differs from that specimen in having no anterior talon, and in having straight ridges.

It may belong to *S. cliftii* or *S. bombifrons*; if it belong to the former, it conclusively proves that tooth *b* cannot be the third milk-molar of that species, as the latter would be far too large to have immediately followed it. If this second milk-molar belong to *S. bombifrons*, as I think probable, it most conclusively proves that the homologous Chinese tooth cannot belong to that species.

The inference from the above would be that there existed a fifth species of *Stegodon* in the Siwaliks, which is the same as *S. sinensis* of Owen; and also that both that species and *S. bombifrons* had a low ridge formula, which shews that they are closely connected with the Mastodons and *S. cliftii*. Professor Owen at page 420 of his notice of the Chinese *Stegodon* suggests that the two imperfect hinder molars, represented in figures 5 and 6 of Plate XXIX A of the F. A. S., which were considered latterly by Falconer to differ from the named species, belong also to *S. sinensis*. The discovery of a tooth in the Siwaliks, which corresponds with the Chinese specimen of that species, confirms that suggestion; I shall hope on a subsequent occasion to be able to present fuller details of the dentition of *S. bombifrons* and *S. sinensis*.

Genus: DINOTHERIUM.

Of this genus Mr. Blanford has obtained from Sind a very beautiful specimen of a ramus of the mandible, containing the four last teeth in perfect preservation; several detached teeth have also been obtained from Sind, as well as a single milk-molar from Kúshalghar. All the specimens seem to belong to *D. pentapotamiæ*; the small size of the new specimen of the mandible quite confirms the distinctness of the latter species from *D. indicum*.

With the addition of the above-mentioned species, two of which are new to the Sub-Himalayan Siwaliks, the Proboscidian Fauna of the Siwaliks of the Western Punjáb is the largest yet known in any one area: it comprehends the following species, all of which are represented in the collection of the Indian Museum:—

Dinotherium pentapotamiæ, nobis.

Mastodon (Trilophodon) falconeri, nobis.

Mastodon (Tetralophodon) latidens, Clift.

Mastodon (Tetralophodon) perimensis, Falconer.

Mastodon (Pentalophodon) siwalensis, Falconer.

Stegodon cliftii, Falconer.

Stegodon bombifrons, Falconer.

Stegodon sinensis, Owen.

Stegodon insignis, Falconer.

Loxodon planifrons, Falconer.

Euelephas hysudricus, Falconer.

Stegodon ganesa may also not improbably occur in the Western Punjáb, but the teeth are undistinguishable from these of *S. insignis*, and no cranium has been found.

The distribution of the Indian fossil Proboscidea, as far as I can at present determine it, seems to be as follows:—

DISTRIBUTION OF INDIAN FOSSIL PROBOSCIDA.

[The abbreviations of localities used in the table are as follows: B., Burmah. D., Siwaliks of Dehra Dun District. De., Deccan. C., China. J., Jamna Valley. K. Kach. N., Nerbudda Valley. P., Western Punjab. P. I., Perim Island. S., Sind. The following refer to books: A. S. B., Falconer's "Catalogue of Fossil Vertebrata in Asiatic Society of Bengal." F. A. S., "Fauna Antiqua Sivalensis." P. M., "Palæontological Memoirs." R. G. S. I., "Records of Geological Survey of India."]

Dinotherium indicum, P. I.¹

Dinotherium pentapotamiae, K.; P.; S.

Mastodon (Trilophodon) falconeri, P.; S.

Mastodon (Trilophodon) pandionis, De.²

Mastodon (Tetralophodon) latidens, B.³; D.; P.; P. I.⁴; S.⁵

Mastodon (Tetralophodon) perimensis, P.; P. I.; S. (?).

Mastodon (Pentalophodon) sivalensis, D.; P. I.

Stegodon cliftii, B.; P.

Stegodon bombifrons, D.; P.

Stegodon sinensis C.; D. (?); P.

Stegodon insignis, D.; P.; N.⁶

Stegodon ganesa, D.; N.⁷

Loxodon planifrons, D.; P.

Euelephas hysudricus, D.; P.

Euelephas namadicus,⁸ N.; J.

In the table of Proboscidea given on page 14 of the "Palæontological Memoirs" certain species, such as *M. latidens* and *S. cliftii*, are mentioned as occurring in "Southern India," and not in the Siwaliks; this question has already been sufficiently discussed above.

¹ F. A. S., pl. 3.

² Pal. Mem., Vol. II, p. 15.

³ A. S. B., p. 11.

⁴ A. S. B., p. 206.

⁵ A. S. B., p. 256.

⁶ A. S. B., p. 316.

⁷ R. G. S. I., X. p. 31.

⁸ I am informed that during the past year Professor Leith-Adams, in the publications of the "Palæontographical Society," has endeavoured to prove the identity of the Nerbudda Elephant with *E. antiquus* of the pliocene of Europe. I have not at present seen the Memoir in question, and therefore cannot discuss the question fully. I may, however, observe that Dr. Falconer, who named the two species, considered them as distinct, but closely allied (Pal. Mem., Vol. II., p. 108); of the Indian species Dr. Falconer remarks (*sup. cit.*, p. 642): "It (*Elephas namadicus*) belongs to the same group, *Euelephas*, as the existing Indian Elephant, but it is broadly distinguished from that species and from all other known species by a very marked peculiarity in the form of the cranium, in addition to dental and other characters."

ARTIODACTYLA.

SUINA.

Genus: HYOTHERIUM.

A considerable number of detached molars of both bunodont and selenodont pig-like animals have been obtained by Messrs. Blanford and Fedden from Sind; to some of these specimens I have already referred at pages 76 and 225 of the tenth volume of this publication.

At page 76 of that volume I shortly described certain upper molar teeth which I then referred to *Sanitherium schlagintweitii*, thinking that they agreed in size with the lower molars of that species, and that from their form they could not belong to any European genus; I, however, pointed out their resemblance to the molars of *Hyotherium* (or *Chærotherium*, as it is often called).

I now find that these teeth do really belong to *Hyotherium*; the first specimens were distorted and crushed, and consequently were altered from their true form; those specimens, moreover, were unusually small, and were both first molars: the last molars, which have now been obtained, shew that they are too large to have belonged to *S. schlagintweitii*.

Some of the smaller of these upper molars are almost identical in form with certain teeth of *H. medium* from the upper miocene of Weissenau, in the collection of the Indian Museum; they are, however, of larger size, and are therefore probably distinct; if such be the case, I shall propose to call the Sind form *H. sindiense*.

It will be inferred from the above that the upper molars of *Sanitherium* are still unknown; the name of that genus must also be removed from the list of the tertiary Mammalia of Sind.

ANTHRACOTHERIUM, RHAGATHERIUM, AND CHÆROMERYX.

The confusion caused by the reference of teeth of two distinct genera to *Chæromeryx* (*Anthracotherium*) *silistrensis*, has been so great, that it is somewhat difficult to recover from it. It will be remembered that at page 225 of the tenth volume of the "Records" I separated the five-columned tooth, which had been referred to the above species, from the four-columned teeth which really belong to *C. silistrensis*; and that, at the same time, I considered that the former might possibly belong to *Rhagatherium*, though I was not certain of this (owing to the fact that we have scarcely any specimens of European genera of extinct pig-like animals in the Indian Museum for comparison). It has subsequently occurred to me that there is really no reason, as far as I can gather from their form, for separating the five-columned teeth in question from the genus *Anthracotherium*, although they resemble in some points those of the closely allied *Rhagatherium*; and that consequently Pentland was really right in assigning the five-columned tooth from Sylhet to *Anthracotherium*, but that he was wrong in assigning also the four-columned teeth to the same genus and species; subsequent authors, as I have said in my former notice, erred in referring the five-columned tooth to *Chæromeryx*, which genus was made expressly for the four-columned teeth.

Considering, then, that there is really no reason for separating the five-columned teeth from Sind and Sylhet from the genus *Anthracotherium*, it will occur to the reader that at page 78 of the tenth volume of the "Records" I described under the name of *Anthracotherium punjabiense* a lower jaw of a species of that genus obtained from the Siwaliks of the Punjab, and that I then remarked, "although these teeth belong to an animal of about the same size as *Chæromeryx*, they cannot be referred to that genus, as they present no generic points of difference from the teeth of the European species of *Anthracotherium*." Now, since we have found that the upper five-columned teeth falsely referred to *Chæromeryx* really do belong to *Anthracotherium*, it will be pretty evident that as they agree in size with the lower molars assigned to *A. punjabiense* that they really belonged to the same species.

Now, with regard to the specific names, it is pretty evident that Pentland, in giving the name of *Anthracotherium silistrense* to the Sylhet teeth, relied upon the larger five-columned tooth, neglecting the distinct characters of the smaller four-columned teeth. It is also tolerably evident that Pomel, in making the new genus *Chæromeryx*, founded it on the evidence of the four-columned teeth, the original figure¹ of the five-columned tooth being indistinct, though a second figure given in the "Fauna Antiqua Sivalensis,"² and apparently copied from the original, is distinct.

I therefore think that the name *Anthracotherium silistrense* must apply to the five-columned teeth from Sind and Sylhet and also to the lower jaw from the Punjab, and that consequently my two specific names of *sindiense* and *punjabiense* must be abandoned.

With regard to the specific name of *Chæromeryx*, I cannot find in the original notices that the specific name of *silistrensis* is coupled with this genus; but since *Chæromeryx* is quoted as being equivalent to *Anthracotherium silistrense*, it appears evident that the specific name was intended to apply to that genus, though that genus has really no right to it. One would therefore be at liberty to assign a new name to *Chæromeryx*, but I think it best to continue to apply the name of *silistrensis* to the species, irrespective of the question of the identity of the genus with *Merycopotamus*.

The synonymy of *Anthracotherium silistrense* and *Chæromeryx silistrensis* will therefore stand as follows:—

ANTHRACOTHERIUM SILISTRENSE—Pent. (excluding four-columned teeth).

Syn. *Anthracotherium punjabiense*, Lyd.

Rhagatherium (?) sindiense, Lyd.

Chæromeryx, Pomel, in parte.

CHÆROMERYX SILISTRENSIS, Pomel (excluding five-columned tooth).

Syn. *Anthracotherium silistrensis*, Pent., in parte.

I regret the part which I have taken in adding to this confusion of names; but under the circumstances it was almost unavoidable until I discovered the original errors in identification.

¹ Trans. Geol. Soc. Lond., Ser. II, Vol. II, pl. 45, figs. 4, 5.

² Pl. 68, fig. 23.

Both the upper and lower teeth of *Anthracotherium silistrense* are exceedingly like, both in size and form, to the teeth of an *Anthracotherium* from the brown-coal of Bonn (oligocene), described by Dr. Boettger under the name of *A. breviceps* (Troschel, sp.);¹ the lower molars of the Indian and European forms are identical in size, while the Indian upper molar is rather larger than the European. If the two forms belong to one species (which I cannot decide without comparing the specimens together), the specific name of *silistrense* would stand, since this name was published by Pentland in 1829, while the specific name of *breviceps* was given by Troschel in 1849.²

Irrespective of the, at all events, closely allied European form, *Anthracotherium silistrense* had a very wide range in India, having been found in Sylhet, in the Punjab, and in Sind. I have already referred to the possibility of the lower jaw of this species from the Punjab having been derived from a zone below that which produces the great majority of mammalian fossils; the occurrence of the genus in the Sind Siwaliks agrees well with the general older types of mammalian genera which occur in that area; among these older genera, we may specially mention *Hyopotamus* and *Hyotherium*, which in India have not hitherto been found beyond the Sind area, and which in Europe did not survive, as far as we yet know, beyond the lower miocene period.

MERYCOPOTAMUS-LIKE ANIMALS.

It will perhaps be remembered that at page 78 of the previous volume of the "Records" I briefly noticed a single upper molar tooth of an extinct Siwalik animal allied to *Merycopotamus*, and which I thought belonged to a new genus. During the past season Mr. Blanford has obtained from the Siwaliks of Sind two more imperfect upper molars of the same species, and in addition a penultimate lower molar of an animal of this class, which in size agrees well with the upper molars, and which does not belong either to *Merycopotamus* or *Hyopotamus*; I think it is, therefore, extremely probable that this lower molar belonged to the same animal as the above-mentioned upper molars. The lower molar is distinguished from the corresponding tooth of *Merycopotamus* by having a lower crown, by the transverse valley being nearly blocked instead of freely open on the inner side, by the worn dentine surfaces of the inner and outer columns being of nearly equal width, and by the dentine surface of the inner column being equal to the whole length of that column, instead of occupying its summit only as in *Merycopotamus*. The form of the same dentine surfaces also distinguishes this tooth from that of *Hyopotamus*, in which, as is well shewn in Professor Owen's figure on plate viii of the fourth volume of the "Quarterly Journal of the Geological Society," the dentine surface of the outer column is large and wide, while that of the inner column only occupies the summit of the column, and not its whole length; the inner column of the new tooth is flatter and less conical than in either *Hyopotamus* or *Merycopotamus*.

¹ Dunker and Zittel's Palaeontographica, Vol. XXIV, p. 163.

² Boettger, *sup. cit*

The entire distinctness of these upper and lower molars from those of any known genus confirm the conclusions previously arrived at as to the distinctness of the genus to which they belong. I propose to call the new genus *Hemimeryx*.

Besides the above-mentioned specimens, Messrs. Blanford and Fedden have also collected from the same formation several detached upper molar teeth, which belong to two other species of *Merycopotamoids*, apparently generically distinct from any of the above, or from *Chæromeryx*. Both these types of teeth are of small size, the one is considerably larger than the other; they belonged to animals intermediate between the bunodont and selenodont suina; both types carry four cones only on the masticating surface; one lower molar, probably belonging to the same species as the larger upper molars, has also been obtained. Mr. Fedden has also obtained from Sind the hinder half of a cranium of a *Merycopotamoid*, which, I think, may probably have belonged to the same species as the larger of the molars in question. Should further researches prove, as I think will be the case, the generic distinctness of these teeth, I shall propose the name of *Sivameryx* for the new genus. All the above specimens will be subsequently figured.

Of the Sind *Hyopotamus*¹ the Indian Museum has received two imperfect specimens of the last lower molar: these teeth agree very closely in character with the European *H. bovinus*; we have also received a portion of a lower jaw containing sections of the bases of the two last lower molars, which agree in form and size with the last-mentioned lower molars. The fragment agrees very closely with the corresponding portion of the lower jaw of *H. bovinus* figured in the above-mentioned paper of Professor Owen's. The depth of the Sind jaw is 1·3 inch, and the length of the section of the last molar 1·32 inch; these dimensions seem to be identical with those of *H. bovinus*; the upper molars of the Sind species are, however, less concave on the external (dorsal) surfaces of the outer columns than those of the European species.

From the perusal of this and other papers by myself on the same subject, it will be gathered that the Sind Siwaliks afford us evidence of the former existence in that area of a very large assemblage of both bunodont and selenodont pig-like animals; a group which is very sparingly represented in the typical Siwaliks, and of which *Merycopotamus* seem to have been the last representative, the group having now entirely disappeared from the living faunas of the globe.

We cannot help having a feeling of regret that these interesting animals are at present only known to us from the evidence of isolated teeth or of a few fragmentary crania and bones. The separation of the upper and lower teeth which generally happens in Siwalik fossils often renders it a matter of extreme difficulty to refer the upper and lower molars to their respective owners, as is exemplified in the case of the above-mentioned teeth of *Hyotherium* and *Anthracotheerium*.

I am not sure whether *Merycopotamus* occurs in Sind or not, as the bones which I at first thought belonged to that genus which have been obtained by Messrs. Blanford and Fedden may very probably belong to some of the allied

¹ Rec. Geol. Surv. India, Vol. X, p. 77.

genera. There are no unworn molars from Sind which I can refer to *Merycopotamus*, but it is just possible that certain much-worn molars may really belong to it.

Genus: *Sus*.

Of this genus two species, *S. giganteus* and *S. hysudricus*, have already been named from the Siwaliks; another species (*Sus pusillus*) was made by Dr. Falconer from the lower jaw of *Sanitherium schlagintweitii*. Among Mr. Theobald's Siwalik collection from the Punjáb there are two fragments of mandibles of a species of *Sus* which are so small that they cannot possibly have belonged to *Sus hysudricus*, which is the smallest of the named species. The most perfect of the two specimens is a part of the left ramus of the mandible containing the three true molars of the permanent dentition, which prove that the specimen belonged to a fully adult animal. The teeth of the species of the genus *Sus* are so like one another in form that it is generally impossible to tell one species from another by the teeth alone: except in the matter of size I cannot distinguish between the teeth of the small specimen and those of *S. hysudricus*, though the accessory tubercles in the outer valleys of the last molar seem to be somewhat larger in the former. The discrepancy in the size of the present specimen and of the jaw of *S. hysudricus* is, however, so great, that on this evidence alone I have referred the two specimens in question to a new species, for which I propose the name of *S. punjabiensis*; the species is, I believe, the smallest of the genus. Below I have given the dimensions of the specimen, and have added for comparison the corresponding dimensions of the smallest specimen of the lower jaw of *S. hysudricus* which is contained in the collection of the Indian Museum:—

	<i>S. punjabiensis.</i> <i>S. hysudricus.</i>	
Length of three true molars	1·46	2·35
„ of last molar	0·61	1·19
Width of „ „	0·38	0·65
Length of penultimate molar	0·49	0·70
Width of „ „	0·35	0·55
Length of first molar	0·32	0·50
Width of „ „	0·29	0·45
Depth of jaw at last molar	0·69	1·70

Sus giganteus, Falc.

From the red and gray Siwalik sandstones of Niki in the Punjáb, Mr. Theobald has sent a very magnificent cranium of this species, which is the largest and most perfect yet obtained. The lower jaw is attached to the cranium, and the whole of the dental series is complete; in fact, the only noticeable damage that the specimen has received is a certain amount of lateral squeezing.

This cranium was obtained from the deposit which I have already referred to, in which were buried such a vast number of bones in a small area; to the left side of the cranium of the pig was attached a cranium of a young *Mustelodon*, which was necessarily somewhat damaged in the extraction of the former, while between the rami of the mandible was firmly fixed the head of a large Ungulate

humerus, and other bones were in close proximity. I merely mention these facts to shew the number of specimens buried in this one place.

The cranium, except in the matter of its vastly superior size, seems scarcely to differ from that of the living Indian pig; the profile of the fossil is, however, rather more concave. The following are the chief dimensions of the specimen:—

	Inches.
Length from supra-occipital to incisors	23·00
Interval between supra-occipital and angle of mandible	8·00
Width above orbits	5·40
Length of molar series	6·30
" of exposed portion of lower canine	2·50
" " " " incisors	1·40
Diameter of upper canine	1·25
Depth of mandible at last molar	3·80
Width of symphysis of mandible	2·60

In addition to the cranium, Mr. Theobald has also sent down the two median metacarpals of the left foot of a gigantic *Sus*, which doubtless belong to the same species, and very probably, since they are from the same locality, to the same individual; they do not differ, except in size, from the metacarpals of the living pig. I give their dimensions in order that they may be compared with those of the latter; in the second column are given the dimensions of an outer metacarpal of the smaller Siwalik *Sus hysudricus*:—

	<i>S. gigant.</i>	<i>S. hysud.</i>
Length of outer metacarpal	4·50	3·10
Width of distal extremity of outer metacarpal	1·18	0·67
" of proximal " " "	1·50	0·85
Length of inner metacarpal	4·40	

These bones are about the size of the metacarpals of the living Malay Tapir, and indicate that the extinct Indian pig, must have about equalled in size the former animal.

Genus: HIPPOHYUS.

This genus, which is confined to the Siwaliks, seems to have been hitherto known only by the cranium and fragments of the mandible, figured on plates 70 and 71 of the "Fauna Antiqua Sivalensis." Mr. Theobald has collected near Asnot a considerable number of specimens of the cranium and mandible of this genus, and one or two specimens had been obtained from the Punjáb in previous seasons; the great number of specimens obtained from Asnot illustrates the very local distribution of many of the Siwalik mammals. Of the specimens of crania and upper molars recently obtained, some are slightly larger and others slightly smaller than Falconer's figured specimen, but I can see no evidence of specific distinction, the gradation from one to another being so regular.

In the mandibles, however, there is such a difference in the size and proportion of the molars that I cannot but think that there is evidence of a second species smaller than *H. sivalensis*. Below I have compared together the

dimensions of a mandible of *H. sivalensis* (a), and one of the smaller specimens (b) —

	a.	b.
Length of three true molars	3.02	2.30
„ of first molar	0.55	0.45
Width of „	0.52	0.40
Length of second „	0.80	0.70
Width of „ „	0.75	0.48
Length of third „	1.71	1.20
Width of „ „	0.80	0.55

It will be seen from the above measurements of the teeth of the two jaws that those of the smaller jaw are proportionally narrower than those of the larger.

RUMINANTIA.

CAMELOPARDALIS AND HYDASPITHERIUM.¹

Among the large collection of specimens obtained by Mr. Theobald, during his last season's work in the Siwaliks, there occur a considerable number of both upper and lower teeth of various species of Giraffe-like animals, some of which belong to new species, and possibly to new genera, while others illustrate more completely the dentition and affinities of previously known species.

A certain amount of difficulty occurs in referring all these specimens to their respective species, since it is in several cases not easy to say whether certain lower molars should be referred to the same species as certain upper molars: or, again, whether certain lower molars which cannot be referred to the same species as any of the upper molars, should be referred to the same or to a different genus. It will therefore be understood that in regard to the lower molars, some of the determinations are only provisional.

The discoveries of new Giraffoid animals in the Sub-Himalayan Siwaliks are gradually bringing to light a group of animals of whose existence scarcely anything is known in other parts of the world. At the present time there exists of this group only the one Giraffe of Africa, which stands out alone and isolated from all other living Ruminants, and is evidently the last specialized survivor of a lost group. In the miocene of Attica and in the Siwaliks fossil species of this genus occur; and in the former deposits there also occur the remains of the *Helladotherium*, which is the only other European member of the group.

In Asia, we now know of the former existence of at least four genera, namely, *Sivatherium*, *Bramatherium*, *Hydaspitherium*, and *Visiatherium*. Of the third of these genera we now know of the existence of three species (unless one belongs to a new genus), one of which is intermediate in the form of the mandible between the *Sivatherium* on the one hand, and the Giraffe on the other.

It is, of course, much to be regretted that some of the species to be noticed here are only known by fragments of their jaws and teeth, so that we can only

¹ Originally wrongly named *Hydaspidotherium*.

guess vaguely and darkly at the true affinities of their owners; even, however, the bare knowledge of the existence of such highly interesting forms of older mammalian life, has a great importance in all schemes for the classification and evolution of the most specialized class of Vertebrates.

Many of the specimens noticed in the present paper will not require further illustration, and they are therefore described at some length; others, again, will require figuring and more minute description on a future occasion, and are therefore only shortly noticed in the present paper.

Commencing with the genus *Camelopardalis*, we may notice that but few molars have hitherto been found, and that consequently the present specimens considerably enrich our knowledge of the Indian fossil species. In the true upper molars I have only found evidence of one species, namely, *C. siwalensis*; certain lower molars and premolars, however, seem to indicate the former existence of a second larger species, and of a third smaller species.

The specimens collected by Mr. Theobald are the following: a portion of a left maxilla containing the three molars; a portion of a right maxilla, which seems to have belonged to the same individual, and contains the two last premolars and the two first molars; the two last upper molars of the right side; two detached penultimate upper molars; two detached upper first molars; a single last upper premolar of the right side; a portion of a right maxilla containing the two last milk-molars and the first permanent molar; a fragment of a left ramus of the mandible containing the two last permanent molars; another fragment containing the last tooth of the opposite side, from beds low in the series; a first right lower molar; a last right lower premolar of large size; a penultimate left lower premolar; the two anterior premolars in a fragment of the right ramus of the mandible belonging to a larger species: and the last lower milk-molar of the left side.

The teeth of the fossil Siwalik Giraffe hitherto figured and described are the two last upper molars, the penultimate upper premolar, the three lower molars, and the last lower premolar; all the above specimens were obtained by Dr. Falconer and are figured on plate 16 of the "Palæontological Memoirs." In addition to the above, a fragment of a mandible with the last premolar and two first molars, obtained by Mr. Theobald from the Punjab, has been figured by myself in the "Palæontologia Indica."¹

In the present paper I shall notice the more important of the recently-discovered specimens, giving the dimensions of some of them. As the majority of these specimens do not differ in character from the corresponding teeth of the living Giraffe, they do not require minute description, nor will it be necessary to give figures of them.

The two most perfect specimens of the maxilla contain between them the five last teeth; of these I have appended the measurements, which are given in the first column (a) of the following table; in the second column (b) I have given

¹ Ser. X, Vol. I, 2, plate VII, fig. 15.

the measurements of the corresponding teeth obtained by Dr. Falconer and taken from page 202 of the first volume of the "Palæontological Memoirs;" while in the third column (c) I have given the measurements of the corresponding teeth of the living *C. giraffa*:—

	a.	b.	c.
	18.	19.	19.
Length of two last molars	2.40	2.50	2.55
" of last molar	1.27	1.21	1.21
Width of " "	1.25	1.40	1.30
Length of penultimate molar	1.19	...	1.11
Width of " "	1.35	1.45	1.45
Length of first molar	1.07	...	1.10
Width of " "	1.10	...	1.20
Length of last premolar	0.98	...	0.90
Width of " "	1.03	...	1.10
Length of penultimate premolar	0.80	1.00	1.08
Width of " "	0.78	1.12	1.22

It will be seen that the present teeth agree very closely in size with Falconer's specimens generally, being, however, slightly smaller. One very important difference distinguishes the dental series of the fossil species from that of the recent species: in the former the last premolar is both longer and broader than the penultimate premolar, while in the recent species the penultimate premolar is both longer and broader than the last premolar. In my above-quoted notice of the lower jaw of the fossil species, I pointed out that the jaw was much deeper than that of the recent species, and that the last premolar was relatively more elongated; and also that the one known cervical vertebra was shorter.

There are, therefore, many points of distinction between the recent and fossil forms, though the resemblance of the true molar series is very close in the two. At page 202 of the first volume of the "Palæontological Memoirs," Dr. Falconer remarks, that the penultimate upper premolar of the fossil species has three tubercles at the inside of the base, which do not occur in the corresponding tooth of the recent species: in Mr. Theobald's specimens these tubercles are likewise absent, and therefore do not seem to be of any specific value: indeed, this tooth appears to be liable to vary in the recent species, as in a specimen of a recent cranium in the Indian Museum, the penultimate upper molar is furnished with a distinct cingulum on the inner side, which is not noticed in Owen's "Odontography," or in Dr. Blainville's figures.

The other specimens of upper true molars collected by Mr. Theobald do not require further notice, as they are in no wise different from the preceding specimens. The specimen of the maxilla with the two last milk-molars has the first tooth somewhat injured: this tooth is narrower in front than behind, as is usually the case in Ruminants: the last milk-molar has a distinct tubercle in the valley separating the inner columns: in the permanent molars of *C. sinensis* there is generally no trace of any similarly-placed tubercle, though some specimens in the Indian Museum and Falconer's original specimens shew a very small one, in the recent species there seems to be always a tubercle in the inner valley of

the upper molars. The dimensions of the specimen with the upper milk-molars are as follow :—

	Inches.
Length of first true molar	1·09
Width of „ „	1·18
Length of last milk-molar	0·98
Width of „ „	0·90
„ of penultimate milk-molar	0·70

The portion of the left ramus of a mandible containing the two last molars, in respect of the last tooth agrees well with Falconer's original specimen of the same tooth; the penultimate molar is, however, somewhat smaller than the corresponding tooth of the lower jaw figured by me in the "Palæontologia Indica," which has already been referred to. Unfortunately the lower part of the mandible of the new specimen has been broken away, but from its thickness at the broken part it would appear that the jaw was deep, as in the figured specimen.

The next specimen, which contains the last molar of the right ramus of the mandible, has a narrower jaw, and therefore cannot have belonged to the same species as the abovementioned figured jaw; the tooth of the new specimen is also somewhat smaller than the corresponding tooth of Mr. Theobald's other specimen of the mandible.

In the following table I have given the dimensions of the figured jaw in the first column (*a*); in the second column (*b*) the dimensions of Falconer's specimen of the last molar; in the third column (*c*) Mr. Theobald's specimen with two molars; in the fourth column (*d*) the jaw of the living Giraffe; and in the fifth column (*e*) Mr. Theobald's specimen with the last molar only; I shall subsequently refer to the specimens under the heads of the above letters :—

	<i>a.</i>	<i>b.</i>	<i>c.</i>	<i>d.</i>	<i>e.</i>
Length of penultimate molar	1·25	...	1·10	1·15	...
Width of „ „	1·00	...	0·90	0·90	...
Length of last molar . . . . .	...	1·7	1·69	1·75	1·40
Width of „ „ . . . . .	...	1·0	0·90	0·90	0·75
Depth of jaw at last molar	2·40	...	...	1·65	1·50

Now, if these measurements are compared with the measurements given above of the upper molars, there can be no doubt but that specimens *c* and *b* belong to *C. sivalensis*, and that specimen *a*, though slightly larger, also must probably be referred to the same. Specimen *e* is, however, as I have said, too small to have belonged to *C. sivalensis*, and must probably be referred to a new species; this specimen, Mr. Theobald tells me, was obtained far below the horizon of the other fossils, and therefore its specific distinctness is the more probable. The depth of the jaw of this specimen is absolutely less than that of *C. giraffa*, but is really proportionally greater, and the species, like *C. sivalensis*, belonged to a deeper-jawed type; thus in *C. giraffa* the length of the last molar exceeds the depth of the jaw by 0·1 inch, while in specimen *e* the depth of the jaw exceeds the length of the last molar by 0·1 inch.

The penultimate tooth of specimen *c* bears a small tubercle in the outer valley, as is the case in the figured specimen *a*; the last molar, as in Falconer's specimen *b*, contains no tubercle in the anterior valley, but has a very small one in the

posterior valley, which does not exist in Falconer's specimen; in the living Giraffe the first molar has a tubercle.

The next tooth which requires notice is a detached last lower premolar of the right side; it agrees precisely in form with the corresponding tooth of the specimen *a* (which is drawn in fig. 14, plate 7, of the above-quoted volume of the "Palæontologia Indica"), but exceeds that tooth in length by 0.37 inch, and is therefore too large to have belonged to *C. sivalensis*, and seems to indicate a third and larger species of Siwalik Giraffe.

The detached first lower molar mentioned in the list of specimens, is of nearly the same size as the corresponding tooth of *C. giraffa*, and doubtless belonged to *C. sivalensis*; it carries a large accessory tubercle in the outer valley.

The penultimate left lower premolar which, I think, may possibly have belonged to a small individual of *C. sivalensis* differs somewhat from the corresponding tooth of *C. giraffa*, and approaches the form of the corresponding tooth of *Sivatherium*, and of the same tooth in the jaws which I refer to *Hydaspietherium*. The hinder barrel of the tooth is very like the same part in *C. giraffa*, with the exception that both the inner and outer columns are somewhat more elongated; the outer column of the anterior barrel is also very similar; the inner side of this barrel is, however, very different. In the living Giraffe, the inner column of the anterior barrel is a simple flattened cone, placed immediately on the inner side of the outer column, there being consequently a central enamel pit in this column; the anterior extremity of the outer barrel curves round to form a simple wall bounding the anterior side of the tooth. In the fossil specimen, on the other hand, there is no separate inner column; the fore-and-aft extremities of the outer column bending round to the inner side, and leaving an open valley between them leading into the central enamel fold; the posterior one of the inner columns of the anterior barrel is simple, while the anterior one forms a large cone, with a central enamel island. The crown of the tooth is low (brachydont), and shews that the tooth belonged to the true Giraffes and not to the Sivatherioids, in which the crowns are tall (hypsodont). The general arrangement of the anterior barrel is very similar to that which occurs in *Sivatherium*, and in the jaw which I have referred below to *Hydaspietherium*; in the two latter genera, however, the antero-internal column of the tooth has its enamel fold forming a cleft on the inner side, and not a median pit.

The dimensions of this tooth are compared below with the corresponding tooth of *C. giraffa*, and I have also added the measurements of the penultimate lower molars of *C. sivalensis* and *C. giraffa*, for relative comparisons:—

	<i>C. siv.</i> Inches.	<i>C. giraf</i> Inches.
Length of penultimate premolar	1.10	0.95
Width of " "	0.70	0.86
Height of crown of penultimate premolar	0.62	0.85
Length of penultimate molar	1.10	1.15
Width of " "	0.90	0.99

It will be observed from the above measurements that the present premolar is relatively longer than in the living Giraffe; in the latter the penultimate lower premolar is considerably shorter than the penultimate true molar; while in *C.*

sivalensis the two teeth are of the same length; moreover, from the width of the premolar, it seems probable that that tooth belonged to a smaller individual than that to which the true molar belonged; and it therefore follows that the penultimate premolar was probably longer than the penultimate molar.

The above-mentioned specimen is, as I have said, rather small for *C. sivalensis*, and yet, I think, it may probably have belonged to a small individual of that species. The next specimen to be noticed consists of the corresponding tooth of the left side, together with the anterior premolar. There is considerable difference between the size of these teeth and that of the last, and yet I should not have thought from this alone that we ought to refer the present specimens to a distinct species; another character, however, to be shortly noticed, shews us that this must have been the case.

The hindmost of these teeth is almost identical in form with the last specimen, the only difference being that the antero-internal column has its enamel fold forming a cleft on the inner side, as in *Sivatherium*, and not a central pit, as in the last specimen. Such a variation in a tooth so liable to vary as an anterior premolar cannot be taken as having any great specific value.

The first premolar is a simple tooth consisting of two main columns in the same antero-posterior line, and a smaller talon-column in front. In the recent Giraffe there is no anterior talon-column; but a small one occurs in *Sivatherium*. Below I have given the dimensions of this specimen, together with the dimensions of the last premolar and two first molars of the lower jaw of *C. sivalensis*, described by me in the volume of the "Palæontologia Indica" above referred to (p. 41), as being the largest specimen known; in the second column I have added the corresponding dimensions of the living species:—

	Fossil. Inches.	<i>C. giraf.</i> Inches.
Length of second molar	1.25	1.15
Width of " "	1.00	0.90
Length of first molar	1.30	1.00
Width of " "	1.00	0.90
Length of last premolar	1.15	0.90
Width of " "	0.90	0.80
Length of penultimate premolar	1.40	0.95
Width of " "	0.81	0.86
Height of " "	0.75	0.85
Length of first premolar	0.96	0.70
Width of " "	0.51	0.55
Depth of jaw at first premolar	1.20	1.70

From the above measurements it will be seen that the present teeth are not too wide to have belonged to *C. sivalensis*; one very important point, however, is against the present specimen belonging to that species. It will be seen from my previously mentioned notice of the lower jaw of *C. sivalensis* that at the second molar that specimen was three-quarters of an inch deeper than the jaw of *C. giraffa*, while the present specimen at the penultimate premolar is half an inch less deep; this, therefore, pretty conclusively proves that the present specimen could not have belonged to *C. sivalensis*, but to a second species with a mandible even more slender than that of the living species; the specimens are too large to

have belonged to the same species as the small specimen I noticed above; but they might have belonged to the same species as the one that has the large detached lower premolar; this, however, we cannot be sure of until we know the form of the jaw to which the latter belonged.

Reverting once more to the premolars, it may be remembered that in the above-mentioned notice in the "Palæontologia Indica," I called attention to the less generalized form of the ultimate lower premolar of *C. sivalensis*, and I have now to add (irrespective of the question of species) that this lengthening of the premolars was common to the whole series in all the fossil Siwalik Giraffes as far as we know; moreover, in their form the two anterior teeth in question approach those of *Sivatherium* and its allies, shewing a closer connection between the two genera. The brachydont form of the teeth under consideration shews that they belong to the true Giraffes. I shall hope to obtain further specimens to indicate the affinity of the new, slender-jawed form, and do not therefore assign any name to the species at present.

Whether any of the lower premolars in question belonged to *Camelopardalis sivalensis*, or whether they belonged to some other nearly allied animal, is in great part immaterial to the real interest of the specimens, which conclusively prove that there existed at least one species of Giraffe in the Siwalik period, of which the lower premolars manifested affinity with the *Sivatherium*-like animals, while in the slenderness of its lower jaw, and in the brachydont character of its teeth, it was most nearly related to the living Giraffe. We have also seen that there appears to be good evidence of three Siwalik species of Giraffes, one very large, one of the size of the living species, and one much smaller; other specimens are much needed to throw further light on the first and second species.

The only tooth requiring notice here, which belongs in all probability to *Camelopardalis sivalensis*, is a third lower milk-molar; this tooth belongs to the right ramus of the mandible; it is a three-barreled tooth, each barrel containing two columns, and the anterior barrel being the smallest of the three; these two latter characters serve to distinguish the tooth from the third lower true molar, in which the hinder barrel consists only of one column, and is consequently the smallest of the three; the general form of the barrels is very similar to those of the permanent molars, the smaller size being the chief distinction; both of the valleys on the external side contain accessory tubercles. The length of the tooth is 1·2 inch, and its width 0·6 inch; I may observe here that this tooth is somewhat longer and narrower than the penultimate permanent lower molar, and also exceeds the length of the penultimate upper molar in the smaller specimen noticed above, by the same extent as it does the lower molar. This is about the proportion that occurs in living Ruminants, and is noticed here, as being of importance in referring certain teeth to be described immediately to their proper owners.

In addition to all the above-mentioned teeth, there is an antepenultimate lower premolar of large size, which belongs to some Giraffe-like animal, but not to the same species or perhaps genus as any of the other teeth; the tooth is upwards of an inch and a quarter in length, which is longer than the corresponding teeth of the large jaw referred below to *Hydaspitherium*, and which, therefore, belonged

to a very large animal. The tooth is brachydont, and the enamel is less rugose than in any of the Sivatherioids, and I therefore refer it to the Giraffes. The tooth posteriorly has a simple oval-shaped pit on its summit equal to about one-third the whole length; anteriorly it has a simple trenchant edge; it is therefore different in form from the corresponding tooth of either the Giraffes or Sivatherioids, and probably indicates a new genus, though I can at present say nothing more definite in regard to it.

We have now to turn our attention to the genus *Hydaspthierium*, of the upper molars of which Mr. Theobald has sent a considerable number of specimens from the Punjab. In a forthcoming memoir on the cranium of *H. megacephalum* now in the press,¹ I have shortly noticed the upper teeth of that species, as well as a single detached specimen of an upper molar, and I have also pointed out the characters which distinguished these teeth from the molars of *Sivatherium*. The new specimens of upper molars have conclusively proved the existence of at least one new species, while another species is known upon the evidence of a lower jaw.

The notices of the specimens of this genus will be somewhat short, as many of them will be figured on a future occasion.

The first specimen that requires notice is a detached left upper molar which is a typical specimen; this tooth is distinguished from that of *Sivatherium giganteum* by its smaller size, by the rugosity of the enamel being less coarse, by the absence of foldings in the central enamel island, and by the form of the external surface or dorsum. This latter character it will be necessary to examine rather more closely. In the upper molars of *Sivatherium*, the dorsum of the hinder barrel carries three bold ridges or costæ, of nearly equal size; the dorsum of the fore barrel contains two similarly bold ridges or costæ. In typical specimens of the upper molars of *Hydaspthierium megacephalum*, the mesial ridges or costæ are very much less prominent; the one on the hind lobe being especially indistinct.

Among the specimens obtained this year are the two last upper molars of the right side, which agree exactly in size with the last-mentioned tooth; in these specimens the costæ are still more indistinct on the dorsa of the hinder lobes, this surface being indeed almost evenly concave, and exceedingly different from the same surface in the molars of *Sivatherium*. Still, the difference in the form of these teeth and of the typical molars of *H. megacephalum* is so slight that I for the present, at all events, consider it best to refer these molars to that species, classing them only as a variety. In the table below I have given the measurements of the single typical tooth which I call variety *a*, and in the second column those of the two aberrant teeth which I call variety *b*; in the third column I have given the dimensions of the two last molars of *S. giganteum*—

	<i>Hydaspth.</i>		<i>Sivath.</i>
	var. <i>a</i> .	var. <i>b</i>	
	In.	In.	In.
Length of last molar	1.56	1.62	2.00
Width of " "	1.60	1.63	2.38
Length of penultimate molar . . . . .	...	1.59	1.68
Width of " " . . . . .	...	1.70	2.20
Height of " " . . . . .	...	1.20	...

¹ Palæontologia Indica, Ser. X, Vol. I, pt. 3.

The two conjoined teeth shew a faint cingulum at the base of the inner columns, which is not observable in the isolated tooth or in the teeth of the cranium of *H. megacephalum*. We have now to consider several other specimens of upper teeth, which have considerable resemblance to the two last specimens, but which are of larger size, and which still further diverge from the *Sivatherium* type, and which must, I think, undoubtedly be referred to a second species of the genus *Hydaspitherium*, for which I propose the name of *H. grande*. The specimen which I will here select for notice is a penultimate upper molar of the left side from the Punjab. This tooth agrees with the teeth of the last specimen in its general form, the dorsum of the posterior barrel overlapping that of the anterior column (owing to the oblique position in which they are placed), and the enamel being rugose, though less so than in *Sivatherium*, and there being no crenulation of the enamel in the central pits.

The chief differences of this tooth from those of variety *b* of the last species, irrespective of size, are, that the crown is relatively much higher; that the anterior costa of the dorsum of the hinder lobe is more prominent and curves more forwards, and that there is no median costa on this surface, which is more concave than in the last specimen; the median costa on the dorsum of the fore lobe is also much less developed; there is no trace of any cingulum on the internal surface of this tooth, nor of any tubercle in the median valley; the summits of the lobes have hardly been touched by wear. The dimensions of this specimen are compared below with the above described penultimate upper molar of variety *b* of *H. megacephalum*—

							<i>H. grande.</i>	<i>H. mega.</i>
							In.	In.
Length of crown	.	.	.	.	.	.	1·80	1·59
Width of „	.	.	.	.	.	.	1·80	1·70
Height of „	.	.	.	.	.	.	1·60	1·20

This tooth, therefore, is squarer than that of *H. megacephalum*, and, differing by only 0·1 inch in width, differs by 0·4 in the height of the crown. These differences, I think, amply justify specific distinction; these teeth from the absence or slight development of the median dorsal costæ present no resemblance to those of either *Sivatherium* or *Bramatherium*. They are nearest, of course, to the variety *b* of *Hydaspitherium megacephalum*, the latter forming a connection between the present specimen and var. *a* of *H. megacephalum*, and those again with *Sivatherium*. As I have before hinted, it is not impossible that the teeth of variety *b* of *H. megacephalum* may really belong to a distinct species, though I do not think we are justified in making any distinction on the evidence of these teeth alone, as they are so close to those of variety *a*.

In addition to the above specimens, Mr. Theobald has obtained three detached upper molars of the same species from the village of Asnot, as well as the two last upper milk-molars of the right side, and two detached specimens of penultimate upper milk-molars of the same side, which from their size and form I have little doubt must be referred to *H. grande*. The ultimate milk-molar repeats the characters on a smaller scale of the larger permanent teeth; the penultimate milk-molar has the first barrel produced into a point anteriorly, which proves that the

two teeth belong to the milk series. The dimensions of the two teeth are as follows:—

Length of last milk-molar	.	.	.	.	.	In.
Width of " "	.	.	.	.	.	1·50
Length of penultimate milk-molar	.	.	.	.	.	1·30
Width of " "	.	.	.	.	.	1·52
						1·00

Having now examined all the types of upper molars of this group of animals contained in Mr. Theobald's collection, it now remains to consider two lower jaws of two species of Sivatherioid animals, which cannot be referred to *Sivatherium giganteum*; both specimens are from the Siwaliks of the Punjab.

The first specimen consists of the greater portion of the right ramus, the only missing parts being the extremity of the coronoid process, and the part in front of the first premolar; the whole of the dental series is complete and but little worn.

I shall here notice this specimen very shortly, as I shall figure it on a subsequent occasion. The ascending portion of the ramus has its anterior border almost at right angles to the axis of the horizontal portion, which distinguishes the jaw from that of *Camelopardalis* (the corresponding part of the jaw of *Sivatherium* is unknown). The horizontal portion is slender and bows outwards to a great extent in the middle, so that the part immediately below the hinder barrel of the first molar is by far the most prominent point in the whole of this side of the jaw. The two latter characters at once distinguish the specimen from the mandible of *Sivatherium*, which is very deep, and which is slightly concave externally.

The teeth are distinguished from those of *Sivatherium* by the costæ on the internal surfaces, and especially those of the hinder barrel, being much less prominent and bold; and by the reticulations of the enamel being finer, as well as by the greater obliquity of their dorsa to their long axes; in *Sivatherium* a rod placed on the last molar will touch both median costæ, while in this specimen it will touch the median costa of the second barrel, and the posterior costa only of the first barrel.

The premolars are very like those of the fragment of a jaw referred above to *Camelopardalis*, but are much larger, and relatively higher, and the enamel is more rugose. In the following table I have given the dimensions of this specimen, of the mandible of *Camelopardalis*, and of *Sivatherium*; the latter dimensions are taken from a cast of the specimen figured on plate twenty-one of the first volume of the "Palæontological Memoirs," the original of which is in the British Museum:—

	<i>Camelo.</i>	Specimen.	<i>Siva.</i>
Length of six molars	6·50	10·30	...
" four last teeth	4·10	7·70	9·00
" from angle of jaw to distal end of molar series	10·50	14·50	...
Height from angle to summit of condyle	5·80	7·50	...
Depth at middle barrel of last molar	1·70	3·30	4·70
" at hind barrel of first molar	1·75	2·52	3·45
" at second premolar	1·55	2·40	3·00
Thickness at first molar	1·00	1·95	2·15
Height of unworn last molar	...	1·70	...

The jaw of *Sivatherium* referred to is probably that of a male, other specimens being slightly smaller; the smaller or female specimens, however, have the same form and proportions as the larger. From the above measurements and comparisons there can be no question as to the distinctness of the specimen from *Sivatherium*.

The teeth are readily distinguished from those of *Bramatherium* by their larger size and greater proportionate height; and from those of *Vishnutherium* by the absence of any cingulum or accessory tubercle, as well as by their much greater size.

There now only remains the genus *Hydaspthierium* of described genera to which the specimen can belong; and from the slight development of the costæ on the dorsa of the upper molars of that genus, and of the lower molars of the present specimen, I think it probable that the latter should be referred to that genus.

With regard to the question of species: the above-referred to cranium of *H. megacephalum* is, from the fact of its bearing horns, no doubt that of a male individual (the female of the allied genus *Sivatherium* being hornless); now, in that specimen the length of the last five teeth of the molar series is only 6·1 inches, while the length of the last five teeth in the present specimen is 9·2 inches; this clearly shews that the specimen could not have belonged to that species.

Then with regard to *H. grande*: this, as we have seen, is only known from upper molar teeth, and there is therefore great difficulty in saying whether or no this specimen belongs to that species; another mandible, however, to be noticed immediately in the character of its lower molars, approaches nearer to the upper molars of *H. grande*, and I have accordingly provisionally referred the second specimen to that species. The present specimen must therefore belong to a third species, for which I propose the name of *H. leptognathus*, with the proviso that subsequent discoveries may render it necessary to change the generic prefix.

The present specimen indicates the existence of a slender-jawed Sivatherioid, which in the form of its jaw is a connecting link between the stout-jawed *Sivatherium giganteum* and *Camelopardulis sivalensis*, in which the jaw is stouter than in the living Giraffe. The perpendicular inner border of the ascending portion of the present jaw is quite peculiar, as far as is yet known.

We have now to consider the portion of a mandible which, I think, may very probably belong to *Hydaspthierium grande*; this specimen comprises a portion of the left ramus of the mandible containing the three true molars and the last premolar; the jaw is broken off posteriorly immediately behind the last molar, and anteriorly some distance in front of the premolar; the teeth are only slightly abraded by wear.

This mandible differs from the last specimen by being much deeper, and by being slightly concave instead of convex on the outer surface; in both of these respects it approaches to the jaw of *Sivatherium giganteum*. The form of the teeth, however, at once distinguishes the specimen from the last-named genus, and also from *H. leptognathus*. The dorsa, or internal surfaces, of the teeth are placed still more obliquely to the long axis of the jaw than in *H. leptognathus*; and the

median costæ are still less developed, those of the hinder barrels being indeed almost obliterated; if a rod be laid on the dorsa of the barrels of the last molar, it only touches the posterior costæ of the barrels, and not the median costa of either barrel, which shows that the form of the teeth is still further removed from that of the teeth of *Sivatherium* than are the teeth of *H. leptognathus*. Perhaps the most distinguishing character of the specimen is the form of the dorsum of the anterior barrel of the last premolar; this surface is fan-shaped, narrower below than above, and nearly flat, the median costa being very slight, and the anterior costa forming a curved boundary to the dorsum. In the corresponding tooth of *Sivatherium* the median dorsal costa is very large, and is the most prominent part of the whole surface, while at the same time the tooth of *Sivatherium* is less fan-shaped. The corresponding tooth of *Hydaspitherium leptognathus* is absolutely taller and narrower than the present specimen, which alone would be a sufficient distinction. I have given below the dimensions of the last lower premolars of the three lower jaws; the tooth of *S. giganteum* is rather more worn down than the others, and therefore is proportionally somewhat squarer—

	<i>Siv.</i>	<i>H. lept.</i>	<i>H. grande.</i>
	In.	In.	In.
Width of dorsum of last premolar . . .	1.40	1.05	1.3
Height of " " . . .	1.72	1.60	1.4

The other dimensions of the specimen are as follows:—

Length of four last teeth	7.7
Depth at middle barrel of last molar	3.7
" at hind barrel of first molar	3.7

From the above comparisons, it is quite evident that the specimen cannot belong to *Sivatherium* or to *H. leptognathus*; the size of the specimen, apart from other characters, distinguishes it from *Bramatherium* and *Vishnutherium*. The specimen, being as large as the jaw of *H. leptognathus*, for the same reasons cannot belong to *H. megacephalum*.

There only remains therefore *H. grande* to which the specimen can belong; now, in the flatness of the dorsa of the molars of the present specimen, as well from their obliquity to the long axis of the jaw, these teeth agree with the upper molars referred to above as forming the new species *H. grande*; the size of the upper and lower molars also agrees well together, and I have accordingly thought it extremely probable that the two belong to the same animal. I wish it, however, to be understood that I cannot be certain in this identification, and that it may subsequently be necessary to refer the lower jaw to a new species or even to a new genus.

The animal to which this jaw belonged was doubtless of the massive type of *Sivatherium*, and therefore widely distinguished from the slender-jawed *H. leptognathus* and the true Giraffes; in the form of its teeth the animal was nearer to the former species, though it diverged still more widely in the form of the inner surfaces of the molars from *Sivatherium* and the Giraffes.

The only other specimen among the collection of teeth of Sivatherioid and Giraffoid animals is a last lower milk-molar of the left side; this specimen I cannot with any confidence refer to any particular species, and I here merely

desire to call attention to it. The specimen in question is far larger than the lower milk-molar which I have referred to *Camelopardalis sivalensis* and cannot belong to that species; it also differs very considerably in form from that specimen, from which I think that it does not belong to that genus.

The tooth is composed of three complete barrels, the hindmost of which is the largest: these two characters assure us that the specimen is a last milk-molar, and not a last true molar. The outer columns of the barrels are set very obliquely to the long axis of the jaw, and the median costa on the one perfect dorsum is slightly developed; in these respects the tooth differs from the true molars of *Camelopardalis* and agrees with those of *Hydaspitherium*. Each of the valleys on the outer side contains a large and pointed tubercle reaching to half the height of the crown. The length of the specimen is 1·9 inch and its greatest width 0·94 inch.

The tooth is slightly longer than either of the two anterior molars of *H. leptognathus*, which is the same relation as exists between the corresponding teeth of *Camelopardalis sivalensis* and ordinary Ruminants: and I think it extremely probable that it should be referred to the former species; it is true that the permanent molars of *H. leptognathus* have no accessory columns like the milk-molar in question, but it not unfrequently happens that the lacteal series does differ from the permanent series in certain points of detail, such differences generally consisting in that the lacteal molars retain ancestral characters which have been lost in the permanent series.

Among the whole of the specimens sent down by Mr. Theobald from the Siwaliks of the Western Punjab, I cannot find any remains which I can with certainty refer to *Sivatherium giganteum*, and it is not improbable that the range of that animal did not extend into the area in question, where it was replaced by the allied genera; no species of this group have hitherto been found in Sind. Among Mr. Theobald's collection there are a considerable number of the limb bones of various Sivatherioid animals, which are generally smaller than those of *S. giganteum*, and which most probably belonged to some of the above described smaller species. I have not yet had time to examine those bones in any detail.

PERISSODACTYLA.

Genus: RHINOCEROS.

During the present and past year the Indian Museum has acquired a large series of specimens of the osteology and dentition of the fossil species of this genus, which have been obtained by the exertions of Mr. Theobald in the Siwaliks of the Punjab, and most especially from the highly fossiliferous beds of the village of Asnot in the Jhelam district.

Among these specimens are the complete adult molar series of *Rhinoceros sivalensis*, the upper milk dentition of *R. palæindicus*, and a complete ramus of the mandible with the symphysis of the same species, and, most important of all, a large series of the upper and lower dentition of the new species *R. pluvius*, which appears to be confined to the Punjab. No specimens of *R. platyrhinus* occur either in the present or in previous collections from the Punjab, and it is not improbable that this species did not occur in that area.

In the present notice I shall only refer to certain upper teeth of *R. planidens*, which are far more perfect than the specimens of upper molars described at page 23 of "Molar Teeth and Other Remains of Mammalia,"¹ and upon the evidence of which the species was founded; and also to a portion of the lower jaw of the same species. The new specimens incontestably prove the distinctness of the species.

Of the two specimens of upper molars which I have selected for notice here, one is the penultimate tooth, and the other the last tooth of the right side. Both teeth are quite complete and in a middle state of wear; they are of such a size that by this character alone they might be well distinguished from *R. sivalensis*, which is the only one of the Siwalik species of *Rhinoceros* with which they have any affinity.

Both of the original specimens on which the species was founded lacked the external surface of the crown, the form of which has been therefore hitherto unknown. In the present specimens we find that the dorsum or external surface is produced into a bold buttress at its antero-external angle, and that the rest of that surface is nearly flat; the presence of this buttress alone is sufficient to distinguish these teeth from those of *R. platyrhinus*.

The other characters of the penultimate tooth are similar to those of the previously-acquired specimens, and need no further notice here. The last tooth, allowing of course for its different form, agrees in general characters with the previous specimen; it is readily distinguished from the corresponding tooth of *R. sivalensis* by its vastly superior size, and by having a very wide cingulum surrounding the outer and inner sides of the anterior collis, and which is continued into the median valley to form a low and wide tubercle at the entrance, of which there is no representative in the corresponding tooth of *R. sivalensis*; the tooth has a small crochet and a large antecrochet.

The dimensions of these two teeth are compared below with the same dimensions of the corresponding teeth of *Rhinoceros sivalensis* :—

					<i>R. plani.</i> In.	<i>R. siva.</i> In.
<i>Penultimate molar.</i>						
Length of anterior surface	.	.	.	.	3.20	2.70
„ of internal surface	.	.	.	.	2.45	1.82
„ of posterior surface	.	.	.	.	2.60	2.34
„ of external surface	.	.	.	.	3.40	2.50
Height of crown	.	.	.	.	2.22	2.10
<i>Last molar.</i>						
Length of anterior surface	.	.	.	.	3.20	2.30
„ of internal surface	.	.	.	.	2.95	1.90
„ of posterior surface	.	.	.	.	3.20	2.35
Height of crown	.	.	.	.	3.05	1.75

The difference in size is, therefore, so great that from this alone there would be no doubt as to the specific distinctness of *R. planidens*, which indeed seems to have been next in size to the largest specimens of *R. platyrhinus*, the largest of any species of *Rhinoceros* with which I am acquainted; the dorsum of the penultimate molar measuring upwards of four inches in length.

¹ Palæontologia Indica, Ser. X, Vol. I, pt. 2.

In addition to these upper molar teeth Mr. Theobald has sent down the symphysis and part of one ramus of a mandible of a species of *Rhinoceros*, which was found with the upper molars, and which I have no doubt from its size belongs to the same species. Before going further, it may be well to remind the reader that the mandibles of three species of Siwalik *Rhinoceros* are figured in the "Fauna Antiqua Sivalensis," and were referred by Falconer to his three species *R. sivalensis*, *R. palæindicus* and *R. platyrhinus*; I do not know on what grounds the lower jaws were referred to their respective species, which were founded upon crania; there is, however, no doubt but that these three jaws belonged to the three above-mentioned species, irrespective of the question of assigning each to each. Now, these three kinds of mandibles all differ from the present specimen, and there is, therefore, every presumption in favor of the Punjab lower jaw having belonged to the Punjab *R. planidens*.

The portion of the lower jaw in question consists of the symphysis, and a part of the right ramus containing the three last premolars and the first true molar; on either side of the symphysis there is a single huge incisor, that of the right side being broken off near its summit, and that of the left at the summit of the alveolus; there are no inner incisors. The single incisor has a flattened surface superiorly, looking upwards and inwards, while the inferior and external surfaces are rounded, the tooth is strongly curved upwards, and extends above the level of the plane of the grinding surfaces of the molars; the jaw is of great vertical depth.

The lower jaw of *R. sivalensis* (F. A. S., pl. 74, fig. 6) has no incisors, and is therefore quite unlike this specimen. In the lower jaw of *R. platyrhinus* (F. A. S., pl. 75, fig. 10), there are two small inner incisors, as well as larger outer incisors; the latter are directed less upwards, and are straighter and smaller than those of the present specimen.

The lower jaw of *R. palæindicus* (F. A. S., pl. 74, figs. 3 and 4) agrees with the present specimen in having the outer incisors only; the latter are, however, smaller and shorter, and are directed very slightly upwards, so that only their extremities reach the level of the grinding surface of the molars; and the jaw is shallower and the symphysis shorter.

In the following table I have compared together the dimensions of the present specimen, with the corresponding dimensions of the mandible of *R. platyrhinus* and *R. palæindicus*; the latter are taken in part from the description of the plates of the "Fauna Antiqua Sivalensis," and in part from specimens in the Indian Museum:—

	<i>R. plan.</i>	<i>R. plat.</i>	<i>R. pal.</i>
	ln.	ln.	ln.
Depth of jaw at last premolar	1.5	...	3.4
Length of symphysis	6.4	6.9	4.5
Vertical diameter of outer incisor	1.8	0.7	1.1
Transverse " "	2.4	1.5	1.3
Length of incisor (broken in <i>R. planidens</i>)	3.5	2.1	1.9
" of three last premolars	5.1	3.8	4.7

No other *Rhinoceros* that I have seen has lower incisors at all approaching in size to those of the present specimen; in correlation with these enormous lower incisors

we should expect that the upper incisors were likewise of unusual size in *R. planidens*, and such appears to have been the case. From the district where the upper molars and lower jaw of *R. planidens* were obtained, Mr. Theobald has obtained two upper incisors of a *Rhinoceros* of gigantic size, which I have no doubt belonged to the same species; the length of one of these specimens is upwards of 4·3 inches, its thickness 1·5 inch, and the height of its crown 1·9 inch. The upper incisors of the other Siwalik species of *Rhinoceros* are not known; the present specimen is, however, far too large to have belonged to *R. sivalensis* or *R. palæindicus*, while *R. platyrhinus* is not known to occur in the Punjab, and if we may judge from Colonel Baker's cranium of this species seems not to have had permanent upper incisors.

The above comparisons point most clearly to the specific distinctness of the gigantic fossil *Rhinoceros* of the Punjab; in its upper molars this species approaches nearest to *R. sivalensis*, but is distinguished by their larger size and their bold cingulum and tubercle in the median valley; in the number of its lower incisors the new species agrees with *R. palæindicus*, but is distinguished by their curved form and much greater size.

Genus: LISTRIODON.

Of this genus, which has still an *incerta sedes*, Mr. Theobald has obtained an upper molar of a very small species quite distinct either from the Indian *L. pentapotamiae* or the European *L. splendens*, or *L. lartetii*, and which must be referred to a new species. The specimen was obtained from the Siwaliks of the village of Jabi in the Punjab, and will be described and figured on a future occasion; I propose to call the species after its discoverer, *L. theobaldi*.

RODENTIA.

Genus: HYSTRIX.

At page 706 of the fourth volume of the "Journal of the Asiatic Society of Bengal," in a list of Siwalik fossils given by Falconer and Cantley, there occurs the name of the genus *Hystrix*, as having been obtained with the other specimens. The name of the genus again appears on page 293 of the fifth volume of the same Journal, and also in the Introduction to the "Fauna Antiqua Sivalensis" (Pal. Mem., Vol. I, p. 23). I can find, however, no further mention of the genus in Falconer's papers, nor any notice of the specimen on which the determination was made; this specimen (or specimens) has, in all probability, been lost.

With the exception of the occurrence of the name in the above lists, we have hitherto known nothing of the occurrence of *Hystrix* in the Siwaliks; towards the end of last year, however, Mr. Theobald forwarded to the Indian Museum a portion of the mandible of a species of this genus, obtained from the Siwaliks of the village of Asnot, which forms the object of the present preliminary notice.

The specimen consists of the middle portion of the right ramus of the mandible containing the two first molars, and the sockets of the last premolar and last molar; the cutting extremity of the incisor of the same side was also obtained.

In this notice I shall content myself with pointing out the main distinctions of the teeth of the fossil specimen from those of *H. leucura*, which are indistinguishable from those of *H. cristata*. The dimensions of the two first molars of *H. leucura* are compared below with those of the fossil teeth:—

					Fossil. In.	Recent. In.
Length of two first molars	.	.	.	.	0·75	0·71
„ of first molar	.	.	.	.	0·39	0·35
Width of „ „	.	.	.	.	0·33	0·29
Length of second „	.	.	.	.	0·36	0·35
Width of „ „	.	.	.	.	0·31	0·28

From these dimensions it will be seen that in the fossil jaw the first molar is longer than the second, while precisely the reverse of this occurs in the recent jaw; the first molar of the fossil is considerably larger than that of the recent jaw, while the second molars of the two are of the same length, but that of the fossil is wider. Since the smallest of the fossil teeth is as large as the largest of *H. leucura*, the matter of size will distinguish the fossil form from the two smaller Indian species, *H. bengalensis* and *H. longicauda*.

Now, for the form of the teeth, in *H. leucura* the lateral enamel fold at the middle of the inner side runs only for a very short distance at right angles to the long axis of the tooth, and is connected for a long time with the fold at the antero-external angle of the crown, and is isolated after its severance; in the fossil jaw this fold runs for some distance at right angles to the same axis, is never connected with the antero-external fold, and is not isolated at all in the specimen. Other differences occur in the form of the grinding surface, which require a figure for their explanation; as minor differences, the surface of attrition of the incisors in the fossil jaw is more concave, and the muscular ridges of the latter are much more strongly marked than in the living species. These differences sufficiently distinguish the Indian fossil *Hystrix* from the living species of the genus.

The only fossils of the genus with which I am acquainted are certain fragmentary specimens from the Val d'Arno¹ of which the species is not determined; *H. refossa* from the sub-volcanic alluvium of Puy de Dome²; *H. primigenia* from the upper miocene of Attica³; and *H. venusta* from the pliocene of North America.⁴

I can say nothing with regard to the unnamed species: *H. refossa* has the enamel islands unusually numerous, and the external fold very slight, and therefore differs from our specimen: *H. refossa* is considered by M. Pomel to be an agouti.⁵ In *H. primigenia* the large inner enamel fold of the lower molars agrees in the matter of length with the same fold in the fossil Indian species, but it seems to be sooner isolated; the form of the minor folds is also different in the two, and

¹ Cuvier: "Ossements Fossiles," 4th Ed., Vol. VIII, p. 128.

² Gervais: "Zoologie et Paléontologie Françaises," pl. XLVIII, fig. 11.

³ Gaudry: "Animaux Fossiles de l'Attique," pl. XVIII, fig. 2.

⁴ Leidy: "Extinct Mammalia of Dakota and Nebraska," p. 343, pl. 26, figs. 23 & 24; the species is there named *H. venustus*, which I have ventured to alter to *H. venusta*, *Hystrix* being feminine.

⁵ Pictet: "Traité de Paléontologie," Vol. I, page 255.

in *H. primigenia* the two first lower molars are of equal length. The molars of *H. venusta* are very large, and the folds simpler than in our specimen.

The Indian fossil cannot, therefore, be referred to any named species with which I am acquainted, and I propose therefore to call it *H. sivalensis*.

Genus: RHIZOMYS, nov. sp. (♀).

From certain beds at the village of Jabi in the Punjáb, which Mr. Theobald classes as middle Siwalik, I have received two detached rami of the mandible of an apparently new Rodent. Each of these rami contains three molars and no premolar; these molars have a single deep enamel fold on the outer side, and three smaller folds on the inner side, which are well apparent in the worn teeth; the last molar is longer than the penultimate; the molars have distinct roots; and the jaw is stout and has well-marked ridges for muscular attachments. The length of the three molars is 0·6, and the depth of the jaw at the second molar 0·5 inch.

To determine the group of Rodents to which these jaws belong I have made use of the classification of the Order *Rodentia* or *Glires* published by Mr. Alston in the "Proceedings of the Zoological Society of London" for 1876. From that memoir the following facts may be gathered as to the number and form of the lower molar teeth in this order:—

In the Sub-orders GLIRES DUPLICIDENTATI and G. HEBETIDENTATI there are always premolars.

In the Sub-order GLIRES SIMPLICIDENTATI, the Sections SCIUROMORPHA and HYSTRICOMORPHA always have premolars. In the remaining Section, MYOMORPHA, premolars may or may not be present. It is therefore clear that our specimens can only belong to this last section.

In this section, the families *Myoidæ*, *Geomysidæ*, and *Theridomysidæ* always have premolars. The families *Spalacidae* and *Dipodidae* may or may not have premolars, while the families *Lophiomysidæ* and *Muridae* never have premolars. It is therefore evident that our specimens can only belong to one of the last four families.

Now, in the three last-mentioned families the molars are always either tuberculate, or carry more or less transverse ridges, and never have external or internal enamel infolds. It is, therefore, clear that our specimens cannot belong to either of these families, and they can, therefore, only belong to the remaining family, *Spalacidae*. This family is divided into two sub-families the *Spalacinae* and the *Bathyerginae*; the latter group has always premolars, while the former lacks them: our specimens can, therefore, only belong to the former.

The sub-family *Spalacinae* contains three well-known living genera, namely, *Spalax*, *Rhizomys* and *Heterocephalus*; of these, the molars of *Spalax* are distinguished from those of the present specimens by having very slight enamel folds, which exist only in the almost unworn state; the lower molars of *Heterocephalus* are distinguished by having only a single inner and outer fold. (Alston.)

There now remains only the genus *Rhizomys* to which our specimens can belong; the lower molars of that genus are characterized by having a large

external enamel fold, and two or more smaller inner folds, which persist till the crown is quite worn down. These characters agree, therefore, perfectly with the characters of our Siwalik specimens, and I can have no doubt but that the latter belong to that genus; I have compared these molars with the teeth of *R. sumatrensis*, and find that they can only be distinguished in form from the latter by the greater depth of the external fold, and by the smaller size of the first internal fold; the fossil molars are in one specimen slightly smaller, and in the other slightly larger, than those of the recent species; the fossil mandible is, however, narrower and slenderer, the incisors much smaller, and there are other differences in the form of the two mandibles which are quite sufficient to specifically distinguish the two forms; these differences will be pointed out on a subsequent occasion. I shall hope to give a figure of the fossil. The fossil teeth are larger than those of any of the other species with which I have been able to compare them: should they belong to a new species, as I think is probably the case, I shall propose to call this species *R. sivalensis*.

It may not be out of place here to observe that among Falconer's undescribed Siwalik Mammalia, there was indicated a new genus under the name of *Typhlodon*. The name only of this genus occurs in the Introduction to the "Fauna Antiqua Sivalensis" (Pal. Mem., p. 23), and from the contents it is evident that this genus belonged either to the Rodents or Insectivores; from the name *Typhlodon* I think that the genus must have belonged to the former, since the name appears to be so evidently derived from *Spalax typhlus*. This being so, and since our new *Rhizomys* belongs to the *Spalacinae*, I think it not at all improbable that Falconer's *Typhlodon* was founded on the same *Rhizomys*. The Introduction in question was published in 1844, and a great part of it was written much earlier in India; it is, therefore, not improbable that Falconer was unacquainted at the time of writing with the genus *Rhizomys*, which was made in 1830,¹ and that finding a Rodent allied to, but distinct from, *Spalax*, he made a new genus for its reception.

The genus *Rhizomys* being confined at the present time to Asia, it was only to be expected that fossil representatives should be discovered in the pliocene of that continent; living species are found in India in the Khasi Hills, and the Sikim Terai. (Jerdon.) I believe that no fossil species of the genus has hitherto been described. An allied genus (*Myospalax*²) has been formed for the reception of the so-called "Quettah mole;" I cannot, however, find that this genus has been described; and I cannot, therefore, say in what respects its dentition differs from that of *Rhizomys* and *Spalax*. The genus is not introduced into Mr. Alston's synopsis.

CARNIVORA.

The remains of Carnivora are of somewhat rare occurrence in the Siwaliks, and therefore almost every specimen obtained is worthy of notice.

¹ Gray, P. Z. S., 1830, p. 95.

² A. S. B., Vol. XI, p. 887; XV, p. 141.

Genus: FELIS.

Of a large *Felis*, which is probably *F. cristata* of Falconer, Mr. Theobald has obtained from Asnot the patella, the distal half of the femur, several metatarsal and phalangeal bones, and the olecranon.

Of a smaller species, the radius, the calcaneum, and a portion of the left ramus of a mandible containing the alveolus of the canine, and the two premolars have also been obtained. I can at present say nothing as to the species to which this lower jaw belonged; it possibly belonged to the same species as the cranium figured on plate XXVII, fig. 1, of the fifth volume of the "Journal of the Asiatic Society of Bengal."

Genus: HYÆNA.

Of this genus Mr. Theobald has collected a tolerably perfect adult cranium, a broken adolescent cranium, exhibiting the carnassial in its alveolus, and a ramus of the mandible; all the specimens seem to belong to one species.

Genus: MELLIVORA.

In the unpublished plates of the "Fauna Antiqua Sivalensis" (Q, fig. 4), there occurs a figure of a cranium which in the Index to the Plates is named *Ursitaxus sivalensis*; now, the generic name *Ursitaxus* was proposed by Hodgson¹ for the Indian ratel, but is now disused in favor of *Mellivora*; *Ursitaxus sivalensis* of Falconer will therefore here and henceforth be called by me *Mellivora sivalensis*.

The above-mentioned cranium seems to be the same as that figured on plate XXVII, fig. 4, of the fifth volume of the "Journal of the Asiatic Society of Bengal" under the generic name of *Gulo*: the specimen is now in the British Museum. On fig. 6 of the same plate of the "Journal of the Asiatic Society of Bengal," a nearly complete right ramus of the mandible of the same genus is also figured; this specimen is not refigured in the "Fauna Antiqua Sivalensis," and I do not know what has become of it.

From the Siwaliks of Asnot, Mr. Theobald has sent the dental portion of a right ramus of the mandible of a species of *Mellivora*, which agrees precisely with the above-mentioned figured jaw; the specimen is somewhat larger than the mandible of *M. indica*, while the figured fossil cranium is rather smaller than that of *M. indica*. These differences in the relative size of the two fossil specimens may be merely due to sex, as there is considerable variation in the size of the sexes of many *Carnivora*; consequently the new lower jaw may probably be referred to *M. sivalensis*. Except in the matter of size, I can see no difference between the mandible of *M. sivalensis* and *M. indica*, and they must have been at all events very closely allied.

Genus: MELES (?).

In addition to the last specimen, Mr. Theobald has obtained from Asnot the left ramus of a mandible which evidently belonged to some animal allied to the badgers, though I cannot be sure of the genus. The specimen shews the base

¹ Asiatic Researches, Vol. XIX, p. 60.

of the canine, and of the second premolar (the first having disappeared), the two last premolars, and the greater part of the base of the carnassial, its summit being broken off.

The premolars are of the simple conodont type of the true badgers, while the carnassial is an extremely elongated and narrow tooth as in those animals; unfortunately its crown being broken away, I cannot compare it with the tooth of the badger. The two last premolars are of nearly equal size, and have no cingulum, which distinguishes the jaw from that of *Mellivora*; the three last premolars are in close apposition, which distinguishes the jaw from that of *Arctonyx*.

The jaw has exactly the form of that of *Meles taxus*, but is considerably larger; and I think it probable that the specimen should be referred to a new species of that genus. *Meles* is not found living in India, but occurs in Tibet and Persia,¹ and a skin was obtained by the late Dr. Stoliczka in Kashgaria, which renders it not improbable that the genus may exist in that country.

Genus: AMPHICYON.

Of *Amphicyon palæindicus* Mr. Fedden has collected in Sind a portion of a right ramus of a mandible, containing the second true molar, and the alveolus of the third; the second molar is very like the corresponding tooth of *A. major*, but the form of the masseteric fossa differs in the jaws of the two species.

Genus: HYLENARCTOS.

Of the genus *Hycenarctos* the Indian Museum has lately received several specimens of the upper dentition, obtained by Mr. Theobald from the Siwaliks of the Punjáb; the new specimens comprise a right maxilla containing the three last teeth, a left maxilla with the three corresponding teeth, and the detached carnassials and first molars of both sides belonging to one individual.

The second specimen and the detached teeth belong to *H. sivalensis*; the first specimen, however, seems to belong to another species. The three teeth of that specimen occupy a shorter space than the same three teeth in *H. sivalensis*, the length of these three teeth in the former being 3.1 inches, and in *H. sivalensis* 3.4 inches. The most striking peculiarity of the smaller teeth is in the form of the first true molar: in *H. sivalensis* the crown of that tooth is oblong in form, while in the new specimen it is somewhat triangular, the apex being on the inner side; the inner ridge in the new specimen is also higher and shorter than in *H. sivalensis*; the carnassial and last molar are very similar in both jaws.

The first molar of the new specimen is somewhat like the first molar of *H. hemicyon* from Sansans,² both alike approaching the form of the corresponding tooth of the dogs and *Amphicyon*; the Indian specimen, however, lacks the inner cingulum, which occurs in the European form, and the former jaw is further distinguished from the latter by the form of the last molar, which is like that of *H. sivalensis*.

¹ Blanford: "Eastern Persia," Vol. II, p. 44.

² Gervais: "Paléontologie et Zoologie Françaises," pl. 81, fig. 9.

The new specimen is unlike any other described species, and must consequently be referred to a new species, which I propose to call *H. palæindicus*.

It may be not out of place here to notice an upper molar of this genus which has been figured by Professor Flower in the August number of the Quarterly Journal of the Geological Society,¹ and which, as well as another specimen, was obtained from the English Red Crag. The figured tooth is the first upper molar of the right side, and agrees exactly with the corresponding tooth of Mr. Theobald's specimens of *H. siwalensis*; the latter tooth being unworn and more perfect than those of Falconer's cranium of this species (with which Professor Flower compared his specimens) are more suitable for comparison with the unworn English specimen. Professor Flower mentions that "the fine striation of the surface of the enamel in lines converging to the apices of the cusps, which is beautifully seen in both the Crag teeth," is very indistinct on the more worn Siwalik teeth; Mr. Theobald's specimens, however, agree exactly in this character with the Crag teeth, and I can but adopt the opinion of Professor Flower that there is no specific distinction between the English and the first-named Indian *Hyaenarctos*.

In noticing the range of the genus, Professor Flower only alludes to its occurrence in Europe and Asia; he might have added that it also occurs in the newer pliocene of South America.²

ALLEGED CETACEAN.

A cast of the bone referred to the Cetacea on page 103 of the ninth volume of the "Records," has been submitted to Professor Flower, who considers that it belongs to the Ungulata and not to the Cetacea; there is, therefore, at present no evidence of the presence of the latter order among the Siwalik Fauna.

THE PALÆONTOLOGICAL RELATIONS OF THE GONDWANA SYSTEM: A REPLY TO DR. FEISTMANTEL, BY W. T. BLANFORD, F.R.S., *Deputy Superintendent, Geological Survey of India*.

Introduction.—I have allowed more than a year to elapse without attempting to answer any of Dr. Feistmantel's remarks in the "Records of the Geological Survey," although I cannot admit that in his reply³ to my first paper⁴ he has either confuted my arguments, or, except in one case,⁵ of which I think he has exaggerated the importance, and twice when I had been misled by his own mistakes, shown me to be in error. My reasons for waiting were partly that I had other matters of greater urgency to attend to; partly that I hoped the irritation which

¹ Vol. XXX, p. 534.

² O. C. Marsh: "Address to American Science Association," Newhaven, 1877, p. 46.

³ Rec. G. S. I., vol. IX, p. 115.

⁴ *Ib.* pp. 79.

⁵ This refers to the presence of *Cycadeaceæ* in the lower Gondwānas. The only error I committed was in overlooking the fact that *Noeggerathia* is classed by many writers as a Cycad. The affinities of this plant are by no means determined with certainty.—See Geol. Mag. 1876, p. 489; 1877, pp. 190, 431; Rec. G. S. I., vol. IX, pp. 118, 140.

Dr. Feistmantel exhibited at finding his conclusions were not immediately accepted might subside; partly, that I feel, in this discussion, that the contest is unequal. Dr. Feistmantel has the enormous advantage of a thorough acquaintance with the literature relating to fossil plants, whilst I possess but a very imperfect knowledge of the subject.

Of the three different papers which Dr. Feistmantel has published in reply to my remarks, it is my intention to notice only one at any length. One of the three papers, that published in the "*Neues Jahrbuch*" for 1877,¹ I have only seen since this paper was first written, the number of the "*Jahrbuch*" which contains it having, through some error of the agents or of the post, failed to reach the Survey library at the usual time. The second paper appeared in the "*Geological Magazine*" for November 1876.² The publication of these two papers is, I think, a misfortune, and I believe Dr. Feistmantel has seen cause to regret having written and published them.

The paper in the fourth number of the "*Records*" for 1876 stands in a very different position; it appears as an official document, and should it not be shown to be erroneous, it will certainly be supposed by geologists generally to have been accepted by the Geological Survey of India, and consequently as entitled to more weight than an occasional paper printed, without any official supervision, in a scientific journal. At the same time I cannot profess to answer every paragraph in detail. Dr. Feistmantel is a voluminous writer, and although there are many statements open to question in the numerous papers which he has already contributed to the Survey publications, I do not see the use of attempting to answer them all; I merely refer to them lest I should be supposed to acquiesce in every statement which I do not attempt to refute. Besides the various notices in the "*Records of the Geological Survey*," a long paper containing descriptions of some fossil plants from the Damuda series in the Raniganj coal field has appeared in the "*Journal of the Asiatic Society of Bengal*,"³ and contains numerous statements of opinion as to the relations of the beds and of their flora. With these opinions, in several instances, I am unable to coincide.⁴

Reasons for publication of previous paper.—As much of the annoyance exhibited by Dr. Feistmantel at the publication of my former paper appears due to my having written it before waiting till he had stated his views at greater length, and specially at my remarks appearing in the same fasciculus as his own, and as he has called attention to this circumstance in the "*Geological Magazine*,"⁵ and in the "*Neues Jahrbuch*,"⁶ I think I am justified in explaining my reasons for acting as I did. Mr. Medlicott, the Superintendent of the Survey, left me

¹ Leonhard und Geinitz, *Neues Jahrbuch für Mineralogie, Geologie und Palæontologie*, 1877, p. 147.

² Dec. II, vol. III., p. 481.

³ J. A. S. B. 1876, pt. 2, p. 329.

⁴ There are also several remarks referring to members of the Geological Survey, and especially to Dr. Oldham, which are neither accurate nor just. See, p. 332, the paragraph commencing "But the fossils"—and p. 373, the fourth paragraph from the top of the page.

⁵ l. c., p. 491.

⁶ l. c., p. 148.

in charge of his office for three months, in July, August and September, 1876, and one of the duties entrusted to me was to edit the number of the "Records" for August. One paper by Dr. Feistmantel, "On the Age of some Fossil Floras in India," had appeared in the previous number of the "Records," and a second was left with me in manuscript. It appeared to me that both these papers were to some extent deficient; that whilst numerous circumstances were stated in favour of the writer's views, some important conflicting evidence was omitted, and that previous observers were treated in some cases not quite fairly. The opinions put forward as to the age of the rocks (and it should be remembered that, in Dr. Feistmantel's two first papers especially, the term "age" appears to be used in a distinctly chronological sense) seemed to me to be much more positive than was justified, even by the evidence adduced, and altogether I thought that if Dr. Feistmantel's remarks were published, it was only right to point out that there was another side to the argument. I thought, and still think, that Dr. Feistmantel would have consulted his own reputation and the interests of the Survey by abstaining from publication until he had given more study to the subject, and until he had more thoroughly mastered the language in which he wrote; but as I was only in temporary charge of the Survey publications, I did not feel justified in refusing to print the paper which had been left with me. I had, therefore, the choice of two courses to pursue: I might as editor have appended a running commentary of footnotes, calling attention to the points in which Dr. Feistmantel's opinions and statements differed from those of other observers, or I might have written a separate paper, explaining the data on which I felt obliged to dissent from Dr. Feistmantel's views. The first course is one which I have personally experienced more than once, and which I have always thought an unfair advantage taken by an editor; I consequently adopted the latter alternative as fairer and more courteous. I printed my remarks in the same number as Dr. Feistmantel's, first, because it appeared to me unjust to others to allow Dr. Feistmantel's statements to appear without comment; secondly, in order to have the advantage of correcting the proofs myself, as it was probable that I should not be in Calcutta when the next number of the "Records" was due. So far as I am able to judge, there was not a single line in my paper to which any objection could be taken on the score of courtesy and fairness, nor can I see that there is any cause for the annoyance which Dr. Feistmantel has since shown. Not only, so far as I can judge, was I perfectly justified in pointing out that there were several omissions in his paper, but it was to some extent a matter of duty to my colleagues to do so, and I endeavoured to accomplish this task without giving Dr. Feistmantel any occasion to suppose that he was harshly treated, or that I underrated the value of his observations. I can only regret having failed in my intentions, and that his reply compels me to call attention to matters I would willingly have forgotten.

Arrangement of present paper.—I proceed to the consideration of Dr. Feistmantel's various papers in the "Records of the Geological Survey," and especially to that which appeared in the fourth, or November, number for 1876. The course I propose to adopt is first to call attention to a few points on which I differ from the writer, or on which I think his remarks are liable to cause error, and then, taking the various groups of the Gondwana system from top to bottom, to

enquire how far Dr. Feistmantel's published views are consistent with facts, and to notice in each case his objections to my arguments. I should perhaps commence by saying that my first objection to Dr. Feistmantel's writing from beginning to end is that he repeatedly omits to state the whole of the facts; he brings forward just so much of the evidence as is in favour of his own views, and ignores the remainder. Of this I shall have occasion to give several instances. I quite believe this to be unconscious and unintentional on Dr. Feistmantel's part, but it tends to invalidate his arguments so seriously, that it is impossible to leave it unnoticed, and it has this most serious disadvantage that, as most of his papers are upon a somewhat abstruse subject, it is almost impossible in general to tell what points have been omitted.

The palæontological contradiction.—On p. 115¹ Dr. Feistmantel points out that on p. 29 he had fully noticed as a palæontological contradiction the discrepancy between the fauna and flora of the Kach group—that is, the Umia group of Dr. Stoliczka. This is correct, and I ought, perhaps, in my paper to have noticed it. Unfortunately, however, any one turning to Dr. Feistmantel's paper to learn his views as to the "age" of the Cutch (Kach or Kachh) beds would assuredly consult pp. 33, 34, where a summary of the conclusions is given. These conclusions appeared to me misleading in two respects: they represented the various localities from which plant-remains had been obtained in Cutch as belonging to two distinct horizons, and the only palæontological contradiction was said to be that plants indicating "generally an age as old as the Bathonian or Bath oolite, and some of them a still older horizon" were from higher beds than the ammonite fauna, which is "not older than Bathonian." I was, I think, fully justified in pointing out that the contradiction was much greater than would be supposed from Dr. Feistmantel's remark.

"Premature conclusions."—At page 117 Dr. Feistmantel writes—

"I would next notice some points relating to the lower Gondwána groups upon which Mr. Blanford's conclusions were rather premature. It will appear (a) . . . (b) that the affinities of our Damuda flora with that of the mesozoic epoch and especially of the triassic formation are overwhelming, and that the arguments for this conclusion are not derived from three species discovered only last year."

A reference to vol. ix, p. 82, will show that this is not a correct representation of my language. I said "main arguments," and by divorcing the phrase from its context, the expression is made to take a very different aspect from that intended. All I wished to point out (*l. c.*) was, that although Dr. Feistmantel might be justified in considering the Damuda flora as triassic, his predecessors, who were ignorant of some of the facts since discovered, should not be blamed, as he had by implication blamed them,² for coming to a different conclusion. The only known connection of any importance between the Damuda flora and the European triassic flora, previous to the discovery of the three Karharbári

¹ Rec. G. S. I., vol. IX, pt. 4.

² See, for instance, Rec. G. S. I., vol. IX, p. 68. "It has been, and will perhaps yet be, endeavoured to show that the Indian Damuda series are of palæozoic age, but I do not see where is the proof, as the palæontological results, *the only possible proofs*, indicate *lower mesozoic*, &c.?" The italics are in the original.

plants belonging to *Voltzia*, *Albertia* and *Neuropteris* was in the occurrence in both of allied forms of *Schizoneura*. In Dr. Feistmantel's own conclusions (*l. c.* p. 77) the only Damuda species said to be triassic were *Schizoneura Gondwanensis*, *Neuropteris valida*, *Voltzia acutifolia*, "and perhaps *Albertia speciosa*," and I was, therefore, I think, not "premature" in concluding that Dr. Feistmantel's "main arguments" for the triassic age of the Damudas, were derived from the three last species, since the occurrence of the *Schizoneura* alone would scarcely have sufficed to indicate the age of the beds.

The differences between the floras of the upper and lower Gondwānas may not be quite so absolute as I thought that they were, but still the difference is very great. The question as to the "analogy with the flora of the lower coal strata in Australia" I will deal with hereafter.

The case of Macrotaeniopteris.—On p. 118, in order to show that the Damuda (lower Gondwāna) formation is closely allied to the upper Gondwāna Rājmahāls, Dr. Feistmantel thus insists on the resemblance between certain forms of *Macrotaeniopteris* found in the two series, and the distinction between them and the European carboniferous forms; in this instance the object is to shew that the Damudas are mesozoic—

"There are amongst the *Taeniopteridæ* two forms which are very near to some from the Rājmahāl Hills, *Macrotaeniopteris danæoides* being very near to *M. lata*, O. M. var. *musafolia* . . . "Of course it may be said again that these are genera of wide range, but yet the species are distinct; so is the *Macrotaeniopteris lata* and *danæoides* well distinct from *Taeniopteris abnormis*¹ or *Germani* or *multinervis* in the carboniferous . . ."

It should be noticed that in the above extract, in order to emphasize the distinction between *Taeniopteris danæoides* and the European palæozoic species, the former is placed in the genus or subgenus *Macrotaeniopteris*, whilst *T. abnormis* is classed with *T. Germani* in *Taeniopteris* itself.

A few pages farther however, (p. 128,) in what is virtually a distinct paper, instead of proving the Damudas high in the series, the object is to show that the upper Gondwānas are low down. The relations between the various species of *Macrotaeniopteris* are again discussed, but with a slight difference. Not a word is said about the Damuda species, but Dr. Sterzel's notice of the close relationship between the Rājmahāl species and *Taeniopteris abnormis* is quoted with approval—

"Dr. Sterzel says about these species (*M. lata*, *M. musafolia*, and *M. Morrisi*) so closely allied with *Taenopt. abnormis*, Gutb., that there is scarcely any difference, and only the formation separates them. For me it is a great satisfaction to see forms, which I have declared to be liassic, so nearly related with a permian one."

Contrast this with the last extract, in which *M. lata* was said to be "well distinct" from *Taeniopteris abnormis*. But this is not all; farther on, at p. 137, a new *Macrotaeniopteris* from the Damudas is described and shown to be intermediate in characters between the Rājmahāl *M. lata* and the permian *M. abnormis*, and this piece of evidence is again brought in to prove the Damudas triassic.

"Our species holds a middle place between the permian *Taenopt. (Macrotaenopt.) abnormis*, Gutb., and the three species of *Macrotaeniopteris* from the Rājmahāl Hills, and we have, therefore, in our triassic beds, between the permian and jurassic, a *Macrotaeniopteris*."

¹ Subsequently said to be permian,

Yet again p. 142, in a description of new fossils from the Damuda (Raniganj) group, *Macrotæniopteris danæoides* is mentioned once more. Here, again, the object being to prove the Damudas mesozoic, *Tæniopteris abnormis* and its affinities are ignored, the resemblance between *T. danæoides* and the Rájmahál forms is again insisted upon, and the old arguments repeated. All the specimens are said to "have a very mesozoic aspect and strikingly resemble certain specimens from the lias (Keuper?) in the Alps."

I admit that this matter is comparatively of trivial importance, but still it is, I think, only right to call attention to it, because it is a typical and characteristic example of what I cannot but consider a radical error throughout Dr. Feistmantel's arguments. The whole of the facts, so far as I know, are stated in one place or another, but the mesozoic or the palæozoic relations of *Macrotæniopteris* are insisted upon, according as the one or the other is in favour of the writer's arguments at the moment.

Criticism of one of Dr. Feistmantel's sentences.—To illustrate the peculiar form of argument further, I will take for criticism a single sentence. Dr. Feistmantel first points out that Dr. Oldham endeavoured to show that the Damuda flora was palæozoic, that this view had been questioned by Sir C. Bunbury, and that subsequent collections afforded "unmistakable evidence" in favour of the mesozoic¹ and, in the writer's opinion, triassic age. He proceeds—

"Already in the old collections from Raniganj there were proofs enough. There were *Schizoneura* very frequent, there were one or two *Sagenopteris*, Presl., *Glossopteris*, different from those in Australia. From Kámthi there were specimens of *Tæniopteris* (*Macrotæniopteris* and *Angiopteridium*) of distinct real *Phyllothea*, like that in the oolites in Italy; there were again a quite different *Glossopteris* from those in Australia, different not only by the shape of the leaf, but especially by the fructification."²

Now, so far as the old collections went, the only Damuda specimens of *Schizoneura*³ which had been determined were from some of the highest beds in the Raniganj group at the top of the Damuda series: the form is locally abundant it is true, but, to the best of our knowledge some years ago, it was only found in the position I have stated. The *Sagenopteris* may be mesozoic, but the quotation of "*Glossopteris* different from those in Australia," is certainly no argument in favour of the mesozoic and triassic age of the Damudas. In the first place, it is only since Schimper's work appeared in 1869 that the species of *Glossopteris* have been distinguished; Dr. Oldham thought differently,⁴ and be it remembered Dr. Feistmantel is in this paragraph imputing blame to Dr. Oldham

¹ l. c., p. 119.

² I, of course, copy these extracts as they are printed.

³ In several papers, and especially in the "Geological Magazine," 1876, p. 488, and "Neues Jahrbuch," 1877, p. 155, Dr. Feistmantel writes of *Schizoneura* as though it were excessively common in the Damuda formation. This is, I think, a mistake. *Schizoneura* abounds in one or two beds in the Raniganj field amongst the very highest Damuda (Raniganj) strata, and a large number of specimens were collected from these beds, so that the plant is peculiarly well represented in the Museum, but so far as my own experience goes, I have only found *Schizoneura* leaves in, I think, two localities in the Raniganj field. The stems may have been found elsewhere, but they are far less common than *Vertebraria* and *Glossopteris*.

⁴ Mem. G. S. I., Vol. II, p. 328.

on the score of the knowledge which existed in 1860-61,¹ not that available in 1876, but even supposing that the forms are distinct, the presence of *Glossopteris* different from those in Australia is no evidence either for or against the age of the Damudas being mesozoic or palæozoic.

The genus *Tæniopteris* (*Macrolæniopteris* and *Angiopteridium*) from Kámthi is the next proof. Now, when Dr. Oldham wrote, the genus *Tæniopteris* had not, to the best of my knowledge, been divided into subgenera, and therefore the relations of the genus as a whole were to be considered. But the genus is palæozoic as well as mesozoic, and Dr. Feistmantel himself admits, p. 137, the affinity between the Kámthi species and the permian one. Moreover, the specimens of *Macrolæniopteris*, if collected by Mr. Fedden, as Dr. Feistmantel states, were not amongst the old collections, for Mr. Fedden first went to Kámthi in 1866, whilst Dr. Oldham's last paper was published in 1861.

Then, amongst the Kámthi fossils there was "distinct real *Phyllothea*, like that in the oolites in Italy." No mention is here made of the connexion with the Australian *Phyllothea*, admitted by every one to be just as closely allied to the Indian forms as the Italian are. This is far from the only instance in which this important alliance is left entirely unmentioned, although it is, of course, noticed elsewhere. As I shall show presently, there is good evidence that the Australian *Phyllothea* occurs in undisputed carboniferous beds.

Lastly, the "quite different *Glossopteris* from those in Australia, different not only by the shape of the leaf, but especially by the fructification," is again urged as proof of the Damudas being mesozoic. I have already noticed this argument, supposing Dr. Feistmantel to be correct in his facts; but is he correct? It will be seen that he admits of no doubt or question; the distinction in shape of leaf and fructification is asserted as a well-known fact, and from the context must be supposed to have been a fact sufficiently clear some fifteen or sixteen years ago. Some quotations from Sir C. Bunbury's paper on the flora of the Kámthi beds of Nagpur will serve to show how far the distinction was admitted as valid. Speaking of *G. Browniana* var. *Indica*, he says—²

"On comparing this Indian *Glossopteris* with the common Australian *G. Browniana*, allowing for the apparent differences produced by the nature of the stone, and the state of preservation of the specimens, I can find no satisfactory specific distinction; the venation is essentially the same . . . The general form varies considerably in the Australian specimens, and is often quite as narrow as in those from Nagpur; the apex also varies in the Australian plant, from very obtuse and even *recluse*, to rather acute, though I admit that it is never, in the specimens I have seen, as acute as in the Indian. I have seen no trace of fructification in Australian specimens, nor is any mentioned by McCoy; on the other hand, I am unacquainted with the rhizoma of the Indian *Glossopteris*. In the absence of these important points of comparison, we cannot feel certain of the specific agreement of the two."

In another place Sir C. Bunbury writes thus³—

"Another and very striking characteristic of this Nagpur fossil flora is its close analogy with that of the coal formation of Australia. The prevailing plant in each of the deposits is a *Glossop-*

¹ 1865 according to Dr. Feistmantel, Rec. G. S. I., Vol. IX, p. 118, but he is in error, as the paper referred to is dated 1st June 1861, and appeared in the first part of Volume III. of the "Memoirs," published in 1861. Dr. Oldham's first paper, too, was published in 1860, not in 1861.

² Q, J. G. S., Vol. XVII, 1861, p. 328.

³ I. c., p. 342.

teris, and it appears (as far as we can judge in the present state of our knowledge) to be actually the very same species in both?"

The above extracts relate solely to *G. Browniana* var. *Indica*, but the typical form of *G. Browniana*,—identical in shape of frond with the Australian species or variety,—was also recognised by Sir C. Bunbury amongst the Nagpur fossil plants.¹ Surely this fact ought to have been mentioned.

Again, as regards the fructification. As is shown above, Sir C. Bunbury (writing in 1861, the year in which Dr. Oldham's last paper was published) had no information as to the fructification of the Australian form. The only information since obtained, as far as I know, is that published by Mr. Carruthers in 1872.² He says, speaking of some specimens from Queensland—

"*Glossopteris Browniana* has been so frequently described and figured, that I find nothing additional worth recording from an examination of Mr. Daintree's specimens, unless it be that one shews some indications of fruit in the form of linear sori running along the veins and occupying a position somewhat nearer to the margin of the frond than to the midrib."

The fructification in the commoner Nagpur form of *Glossopteris* (*G. Indica*, not *G. Browniana*) which is figured in Sir C. Bunbury's paper,³ is of course quite different. But is the evidence of "indications of fruit," observed only in one specimen amongst the numerous fronds of *Glossopteris Browniana* which have been examined, sufficient to justify Dr. Feistmantel's confident assertion that the Kámthi *Glossopteris* differs from "those in Australia" "especially by the fructification?" and why is the existence at Kámthi of *Glossopteris Browniana* identical with the Australian form left unnoticed? and is it fair to quote information first published in 1872, in order to show that a writer in 1861 was guilty of ignorance for not being aware of such facts?

I have criticised this passage at great length in order to show how very much Dr. Feistmantel's statements and arguments are open to question. The sentence I have taken is by no means exceptional, but it is of course impossible to go through the whole paper in the same way.

Proof of mesozoic age.—Still, before quitting this question of evidence, I may perhaps as well deal at once with Dr. Feistmantel's views of what constitutes "proofs of mesozoic age." Mr. Wood-Mason⁴ is said to have brought a suite of fossils affording such proofs. Amongst the forms cited are *Vertebraria* and *Alethopteris Lindleyana*. In another place Dr. Feistmantel writes⁵—

"The Damuda flora exhibits itself quite decidedly as mesozoic and most naturally of triassic age, as out of thirty-one species known at present, there are nineteen distinctly mesozoic forms."

Or again⁶—

"The mesozoic (epoch) is marked by the following peculiar genera (of *Equisetaceæ*).

"*Schizoneura*, Sissimp.⁷

Phyllothea, Bgt.

Sphenophyllum, a peculiar form.

Vertebraria, &c."

Is this not a case of *petitio principii*? One of the questions in dispute is whether the age of the beds in Australia, in which *Vertebraria* occurs, is palæozoic

¹ l. c., p. 329.

² Q. J. G. S. 1872, Vol. XXVIII, p. 354.

³ l. c., Pl. VIII, fig. 1, 4.

⁴ Rec. G. S. I., IX, p. 119.

⁵ l. c., p. 121.

⁶ J. A. S. B., Vol. XLV, 1876, pt. 2, p. 337.

⁷ This is, of course, a misprint.

or mesozoic, and as the genus is unknown elsewhere, except in the Indian rocks, it can only be a mesozoic form because of its occurrence in those Australian beds. Now, those beds are held to be of palæozoic age by authorities whose opinion is certainly entitled to some respect, and, as I shall show presently, the evidence in favour of this view has been, I think, greatly underrated by Dr. Feistmantel. The same argument applies to *Phyllothea* with even greater force, because this genus is stated by Mr. Clarke¹ to occur in the *Glossopteris* beds interstratified with marine carboniferous rocks, and if it be replied that Mr. Clarke may have been mistaken in his identification, and that there were no specimens of *Phyllothea* in the imperfect collection from the lower Australian coal beds examined by Dr. Feistmantel himself, I would call attention to a letter from Professor McCoy to Mr. Daintree printed in the "Quarterly Journal of the Geological Society" for 1867.² Professor McCoy is surely a competent observer, and as he is, and has always been, the most energetic advocate of a mesozoic age for the Australian plant-bearing rocks, his evidence may fairly be accepted in this case. He identified certain plants from Queensland as *Glossopteris Browniana* and *Phyllothea Australis*, and although it is not stated that the *Phyllothea* occurred with the *Glossopteris*, I do not think any one can read the paper without understanding that the association of these two plants in the same beds is distinctly implied, and not only is it said that the *Glossopteris* occurs in beds below those containing carboniferous fossils, but Mr. Clarke expressly states "no *Glossopteris* has been found in Victoria, Queensland, Western Australia, or in New South Wales, except in association with beds containing fossils of palæozoic age,"³ and this same statement has since been repeated even more emphatically by Mr. Daintree.⁴ Again, in another paper,⁵ Mr. Clarke mentions that a plant found by Leichhardt in a bed "in the midst of, and far below," others with lower carboniferous animal forms, was afterwards found to be a *Phyllothea*. In the face of all this evidence is it correct to write of the genus *Phyllothea* as a proof of mesozoic age, or to quote it as a type peculiar to mesozoic strata?⁶

As regards *Sphenophyllum*, the distinctions between the Damuda *S. speciosum* (or *S. trizygium*) and the palæozoic species may be of great importance, but still the fact remains that, except in Damuda rocks, the genus is only known from palæozoic strata. Surely Dr. Feistmantel does not mean to argue that the peculiar form is mesozoic because it occurs in Damuda rocks, and Damuda rocks are mesozoic because they contain the peculiar form of *Sphenophyllum*? Yet in what other manner can the genus be quoted as evidence of mesozoic age?

¹ "Mines and Mineral Statistics," section No. 1, opposite p. 206 and p. 166, "The Greta beds are not the uppermost with marine fossils, but beds with them lie farther to the east, in which *Phyllothea* has occurred at Harper's Hill." See also the notes by Mr. Wilkinson, l. c., p. 132. These are quoted in p. 139 of this paper.

² Vol. XXIII, p. 11.

³ Q. J. G. S., 1866, Vol. XXIII, p. 10.

⁴ Q. J. G. S., 1872, Vol. XXVIII, p. 288.

⁵ Q. J. G. S., 1861, Vol. XVII, p. 362.

See also J. A. S. B. 1876, Vol. XLV, pt. 2, p. 347.

The nineteen distinctly mesozoic Damuda forms.—I have disposed of two out of the nineteen “distinctly mesozoic forms” in the Damudas, *Sphenophyllum speciosum* or *trizygia* apparently not being included in the number.¹ The beds containing *Neuropteris valida*, *Voltzia*, *Albertia*, and *Glossozamites*, as I will show presently, must be separated from the true Damudas. The other mesozoic Damuda types comprise *Alethopteris Lindleyana*, allied, it is true, to some European mesozoic forms, but equally close to *A. Australis* from the Newcastle beds of Australia or their representatives in Tasmania; *Macroteniopteris*, two species, the affinities of which have already been shown not to be exclusively mesozoic: and *Gangamopteris*, three species, classed as mesozoic on account of the occurrence of the genus in certain beds in Victoria (Australia), the assumption as to the age of which beds depends entirely upon the same evidence—fossil plants—as has been shown to be fallacious in New South Wales. One species of *Gangamopteris*, too, is common to the beds of Victoria, and to those of Newcastle (New South Wales), always classed by Mr. Clarke as palæozoic. It is quite possible that the Victoria beds may be mesozoic,² but there is no evidence that they are newer than the Hawkesbury and Wyanamatta beds of New South Wales, and the animal remains in the latter exhibit palæozoic affinities. It would be quite as just and reasonable to argue on this evidence that the Victoria beds are palæozoic as it is to assume, as Dr. Feistmantel does, that the Australian strata containing *Vertebraria* and *Phyllothea* are mesozoic. It is evident that out of the “nineteen distinctly mesozoic forms” only seven, *viz.*, *Schizoneura Gondwanensis*, *Actinopteris Bengalensis*, *Angiopteridium* sp., three species of *Sagenopteris*, and one of *Noeggeruthia* have, when the Karharbári plants are omitted, any claim to the title, and of these, none, except the *Schizoneura*, can be said to be sufficiently known for their affinities to be clearly ascertained, nor, with the same exception, do any of the plants named belong to characteristic forms. *Actinopteris* is a common living genus, *Sagenopteris* is close to *Glossopteris*, and although it is highly probable that the European and American palæozoic *Noeggeruthiæ* differ from the Damuda types, the latter are allied to Australian forms, and none are sufficiently well understood for their relations to be unmistakable. I fully grant that in arguing thus I am raising minor objections, but my object is to point out that the evidence is strained by Dr. Feistmantel, and that any one arguing on the other side, and using the same style of reasoning, could produce at least as good proof in favour of coming to a diametrically opposite conclusion.

The asserted absence of animals in upper Australian coal-measures.—These remarks tend to become so lengthy, that I can only notice one or two other points before proceeding to the second part of my subject. Dr. Feistmantel’s classification of the Australian coal-bearing rocks³ into Upper and Lower differs entirely from that adopted by Mr. Clarke and other Australian geologists, and the remark appended to the whole of the upper beds, including the Wyanamatta, Hawkes-

¹ Rec. G. S. I., Vol. IX, p. 121.

² See p. 142.

³ Rec. G. S. I., Vol. IX, p. 123. The subject will be found more fully treated further on, p. 137

bury, and Newcastle groups,¹ "No animals," is of course a mistake, as is the statement on the next page, that the rocks of Bowenfels and Newcastle contain "*no animal fossils*" (the italics are in the original). The fact that the animal fossils are fishes with palæozoic affinities is omitted, and as it is impossible to suppose that Dr. Feistmantel was ignorant of this circumstance, the omission affords a good instance of his habit, to which I have already referred, of suppressing all evidence opposed to his views, but I have no doubt the assertion that "no animals are found in the beds" is an oversight, and that the author's intention was to write no *marine* animals.

In the table, however, at p. 125, illustrating the relations between the beds in Europe, India, and Australia, Dr. Feistmantel writes, under the heading of Coal-measures in Australia "(a)—*Upper coal-measures . . . Flora only.*" It is impossible to acquit Dr. Feistmantel of a mistake in a matter of fact in this case.

It is only to be regretted that in this, as in numerous other instances, Dr. Feistmantel has not been more careful in writing his papers and in reading the proofs, since mistakes of this kind are certain to mislead readers who depend upon the writer for their information on a little-known subject, and who are just as seriously deceived by an unintentional slip as by a deliberate misstatement. The error is due to oversight of course, but mistakes in such matters tend to diminish the confidence we should otherwise feel in the writer's accuracy.

Zeugophyllites and *Schizoneura*.—In a footnote, p. 119, Dr. Feistmantel points out that neither the Australian *Zeugophyllites* nor *Noeggerathia*, is a *Schizoneura*, referring at the same time to my having suggested that the Australian *Noeggerathia* might be a *Schizoneura*. In other papers the same matter is referred to and in much stronger language.² The mistake is entirely Dr. Feistmantel's own. In his original paper in the "Records"³ he wrote thus:—

"The fossils described as *Zeugophyllites*, Brgt. from India by Brogniart (Prodrome, 121-175) and subsequently by Strzelecki ('Physical Description of New South Wales, &c.') seem to belong also to *Schizoneura*."

And the same fossil is alternately called *Noeggerathia* and *Zeugophyllites* by different Australian geologists.⁴ I am quite aware that Dr. Feistmantel, in a footnote to his paper⁵ on Raniganj plants, written after my paper was published, asserts that the words "according to Dr. Oldham" have been omitted at the close of the above extract; but Dr. Feistmantel is responsible for the omission, not I. The correction, too, should have been in the "Records," and not in a footnote in the

¹ The occurrence of a fish in the Wyanamatta and Hawkesbury beds is, in fact, mentioned in the next page. The palæozoic affinities of the species are, however, not noticed.

² J. A. S. B., Vol. XLV, 1876, pt. 2, p. 345. "It is also incorrect to consider, as Mr. W. T. Blanford has done, the Australian *Noeggerathia* as ? *Schizoneura*, the two latter genera being quite as distinct as the two former (*Schizoneura* and *Zeugophyllites*) are from one another, and I think certainly that Mr. W. B. Clarke would be able to distinguish a *Noeggerathia* from a *Schizoneura*, and *vice versa*."

³ Vol. IX, p. 69.

⁴ Q. J. G. S., 1861, pp. 359, 360. In the latter page Mr. Clarke himself speaks of *Noeggerathia* (or *Zeugophyllites*).

⁵ J. A. S. B., Vol. XLV, 1876, pt. 2, p. 346.

middle of a long paper, which nine-tenths of the readers of the "Records" in all probability never heard of. As the matter stands, Dr. Feistmantel charges me with his own blunder, precisely as he did in the matter of *Ganganopteris*,¹ although he subsequently apologized for his remarks in the latter case.²

PART II.

The age of the Gondwana groups.

I.—UMIA (*Kach*) AND JABALPUR.—I proceed to answer Dr. Feistmantel's notes on the age of some of the Gondwana groups, and will commence, as he has done,³ with the uppermost, the Umia beds of Cutch (*Kach* or *Kachh*.) It is agreed that the *Cephalopoda* of these beds have uppermost jurassic affinities, and that the plants, which are in strata overlying those containing the *Cephalopoda*, are related to English lower oolitic (middle jurassic) forms, but it is urged by Dr. Feistmantel, in opposition to Dr. Waagen,⁴ that "it is very possible that the full examination of the *fauna* may modify the stratigraphical relations as deduced from the *Cephalopoda*," and again,⁵ "I may here remark that from a cursory inspection I have made of the *Kach* collections, I do not think they will bear out the inferences based upon the *Cephalopoda* as to the Tithonian horizon of the upper members of the series."

It is as well to quote the first passage further. Dr. Feistmantel says—

"There are certainly some mollusca that are generally of older age than Portlandian, passing into the higher beds of *Kach*."

"a.—I may mention only from the Umia group (which contains the Portlandian *Cephalopoda*) the very frequent occurrence of—

"*Goniomya V-scripta*, which mostly occurs in middle jurassic beds in Europe.

"*Astarte major*, Sow., very near with *Astarte maxima*, Om., from middle Jura in Germany.

"A *Trigonia* near *Trigonia vau*, Sharpe, from jurassic beds on the Sunday river in South Africa.

"A *Goniomya* scarcely different from *Goniomya inflata* Ag., a middle jurassic form—also related with *Goniomya rhombifera*, Goldf. from liassic strata.

"A *Trigonia* very near to *T. Herzogii*, Hausm., from Enon on the Sunday river in South Africa.

"Some *Trigonia* allied with *Tr. ventricosa* in South Africa.

"A portion of the lower jaw junction⁶ of a *Plesiosaurus* which has mostly allied forms in the English lias—found near Borooria in the Umia group."

I naturally feel some hesitation in disputing the opinions of the Palæontologist of the Geological Survey on palæontological questions, and especially on so very elementary a subject as the value of palæontological evidence, but I must confess that, supposing even that the above were a correct statement of the affinities of the fossils named (and I shall show that it is not); supposing

¹ Rec. G. S. I., Vol. IX, p. 122.

² Rec. G. S. I., X, p. 76.

³ Rec. G. S. I., Vol. IX, p. 116.

⁴ Pal. Ind., Ser. IX, Vol. I, pp. 225, 233;

⁵ Rec. G. S. I., Vol. IX, p. 135.

⁶ Distal portion or symphysis of the mandible is meant, not, as might perhaps be supposed, the condyle.

that no relations to forms in higher beds have been omitted, and that the evidence is in no case one-sided, all I can say is that Dr. Feistmantel's ideas upon palæontological evidence differ widely from what I have always supposed to be the accepted views of geologists in general. I may be in error, but I should have thought that in upper jurassic strata some species would certainly be found closely allied to middle and lower jurassic forms, and that a few might be identical. I notice that all the species mentioned except the *Plesiosaurus* consist of Lamelibranchiate bivalves (*Pelecypoda*), and that Dr. Waagen, whose opinion on the subject is probably not given without reason, has especially referred¹ to alliances between some of the *Umia Pelecypoda* and those of the Portland beds, and I have always been under the impression that the selection of a few forms from amongst a large number as evidence of the affinities of a fauna is liable to mislead, and that the true relations are only to be determined by a comparison of the whole. From the Portland group itself, there would, I think, be no difficulty in selecting half a dozen species of mollusca allied to middle or lower jurassic forms. Perhaps the value of the evidence adduced, assuming it to be correct, may be best shown by taking a parallel case.

The cretaceous beds of Southern India comprise a group representative of the upper cretaceous rocks (white chalk with flints or Senonian) in Europe. In this Southern Indian group, that of Arialúr, amongst other fossils, the following occur²—

<i>Nautilus Bouchardianus</i> , found in Europe in the gault (middle cretaceous),		
<i>N. Clementinus</i>	”	gault,
<i>Ammonites Velledæ</i>	”	neocomian and middle cretaceous,
<i>A. Deccanensis</i>	} belonging to the group of <i>macrocephali</i> and allied to European	jurassic forms,
<i>A. Arrialoorensis</i>		
<i>Fulguraria elongata</i> (<i>Voluta elongata</i> , D'Orb.) found in European middle cretaceous beds,		
<i>Cerithium trimonile</i>	”	gault,
<i>Euspira rotundata</i> (<i>Turbo rotundatus</i> , Sow.)	”	upper greensand,
<i>Ziziphinus Geinitzanus</i>	”	Hippuritic limestone (Turonian),

besides *Ammonites Gardeni* and *Euchrysalis gigantea*, found also in South African beds supposed to be of Cenomanian (upper greensand) age. These identifications, be it recollected, with the exception of the two *macrocephali* ammonites, are specific; they are not mere cases of related forms, as in the fauna of the *Umia* beds, and the list might be considerably increased if every form allied to European middle or lower cretaceous species were quoted. Yet there cannot be the slightest doubt that the fauna of the Arialúr beds is typically upper cretaceous, taken as a whole. It is, I think, needless to adduce further evidence to show of how little value the argument against the upper jurassic age of the *Umia* beds would be, even if it were correct.

But then comes the question—How far is this evidence correct? Three of the six mollusca mentioned are *Trigoniæ* allied to the South African forms *Tr. vani*, *Tr. Herzogi*, and *Tr. ventricosa*, and Dr. Feistmantel, quite correctly I believe, points out³

¹ l. c., p. 225.

² Rec. G. S. I., Vol. IX, p. 116.

³ Pal. Ind., Ser. I, III, V.

that "there is a great affinity of some of the fossils in the uppermost beds of Kach with forms from the South African strata on the Sundays and Zwartkop rivers." He proceeds to show that these South African fossils were at first supposed by Krauss to be lower cretaceous; subsequently they were classed by Bain as liassic, and finally by Sharpe and Tate as of the same age as the great oolite of England (middle jurassic). Now, Dr. Feistmantel has, I think, overlooked some later information than that quoted by him. Tate¹ is the last writer noticed, and he, like all previous observers, supposed the upper portion of the Uitenhage formation, from which the jurassic fossils described came, to consist of a single group, although he noticed² the occurrence of two cretaceous forms, a *Hamites* and a peculiar *Crassatella* allied to a neocomian species.

In a paper "On some Points in South African Geology"³ by Mr. G. W. Stow, published four years after the appearance of Mr. Tate's description of the fossils, it was shown that the jurassic beds belonging to the Uitenhage formation on the Zwartkops and Sundays rivers comprised several different groups distinguished by their fossils.⁴ The most important section is the following on the lower Sundays river:—

POST-TERTIARY.

UPPER JURASSIC—

1. Few and small *Trigoniæ*.
2. Zone of *Trigonia ventricosa* and *Tr. vau*, with *Gervillia dentata*, *Exogyra imbricata*, &c.
3. Few *Hamites* and wood.
4. Zone of *Modiola* (*M. Baini*) and *Hamites*, *Belemnites* (*B. Africanus*), *Ancylorceras* (?), *Trigonia Goldfusi*, *Crassatella complicata*.

Strata hidden.

LOWER JURASSIC—⁵

5. *Astarte Herzogi*, *Trigonia Herzogi*, *Pleuromya lutraria*.

Before proceeding further, it is perhaps as well to notice that, of all the *Umia* species mentioned as having supposed middle or lower jurassic affinities, the most important is *Trigonia ventricosa*, because it and another *Trigonia*, *Tr. Smeei*, are amongst the commonest and most characteristic fossils of the group, and because both forms are also found on the eastern coast of India in beds associated with others containing upper Gondwana plant-fossils. *Tr. ventricosa* too, it should be remembered, is closely allied to the Indian middle cretaceous *Tr. tuberculifera*.⁶

¹ Q. J. G. S. 1867, Vol. XXIII, pp. 139, 164, 169, &c.

² l. c., p. 165.

³ Q. J. G. S. 1871, XXVII, p. 497.

⁴ See especially l. c., fig. 3, opposite p. 500.

⁵ The term 'lower' is probably merely intended to signify that the beds named are inferior in position at the locality. The age of these beds cannot well be earlier than lower oolitic, which is by many geologists classed as middle jurassic, lias being lower jurassic.

⁶ Pal. Ind., Ser. VI, p. 315. In a footnote to the description of this shell, Dr. Stoliczka points out that although some of the fossils associated with *Tr. ventricosa*, and described, together with that species, as cretaceous by Krauss, are clearly jurassic, others appear to have cretaceous affinities. Dr. Stoliczka wrote in 1871, before Mr. Stow's paper appeared.

For the moment, it will be as well to attend to *Trigonia ventricosa* and *Tr. van* alone. Both these shells were found elsewhere in the district near Port Elizabeth in beds supposed to be at a lower horizon, but they are there comparatively rare and isolated,¹ whereas in the uppermost bed on Sundays river they are so extremely abundant as to be characteristic. The next bed below the *Trigonia* zone is very important, because it is the only one containing *Hamites Africanus* and the lowest with *Crassatella complicata*, both forms with distinct cretaceous affinities,² but another species peculiar to the bed is *Belemnites Africanus*, a near ally of *B. Grantianus* (*B. Kunkotensis* of Waagen) one of the most typical fossils of the Katrol group of Cutch, and ranging into the bottom beds of the Umia group. At the same time amongst the remaining fossils in the *Modiola* and *Hamites* Zone on the Sundays river one is identified with *Trigonia Goldfusi*,³ a lower oolite (middle jurassic) fossil, and *Modiola Baini* is also related to a great oolite species, but the *Modiolæ* and *Mytili* are by no means characteristic forms, and cretaceous or even later allies might easily be indicated. In another stratum on the Upper Sundays river,⁴ together with *Modiola Baini* and apparently on the same horizon, *Ammonites subanceps* is found, and this form is but dubiously separable from *A. anceps* of the lower Châri beds in Cutch and Callovian of Europe. It is thus evident that there is too large a representation of middle jurassic fossils to justify the reference of the *Hamites* bed to neocomian, but still there can be no question of its occupying a very high jurassic horizon, and the zone of *Trigonia ventricosa* and *Tr. van* is even higher.

Trigonia Herzogi, in the section on Lower Sundays river, was only found at a considerably lower horizon than *Tr. ventricosa*, but on Upper Sundays river it was found in a bed overlying the *Modiola* zone and apparently, according to Mr. Stow, as high in the series as the *Tr. ventricosa* band.

Gervilla dentata of the Hamite bed on Sundays river is apparently identical with a species found in the Umia group. If not identical, the forms are very closely allied.

A comparison of Mr. Lydekker's remarks⁵ on the fragment of a *Plesiosaurus* mandible from the Umia beds, will show that Dr. Feistmantel overrates the importance of the occurrence. *Plesiosaurus* ranges from lias to cretaceous, and the occurrence of more numerous species in the former is due to the preservation of many specimens at one favoured locality. As the mandibles of the upper oolitic and cretaceous forms are not known, the fragment from the Umia beds was at first compared to a liassic species, but it subsequently proved to be distinct.

The specimens attributed to *Goniomya V.-scripta* I am unable to find in the Survey collections. It is possible that there may be some mistake about the identification, and I have reasons for believing that the fossils at first supposed

¹ l. c., p. 502.

² See Tate: Q. J. G. S., 1867, vol. XXIII, pp. 150, 160, 165.

³ This species, however, in South Africa appears to pass up into beds of probably cretaceous age. Stow: l. c., pp. 513, 514,

⁴ Stow: l. c., p. 503.

⁵ Rec. G. S. I., vol. IX., p. 154; vol. X., p. 41.

by Dr. Feistmantel to represent the *Goniomya* belong to *Trigonia* *vau.* The only *Goniomya* I can discover certainly resembles *G. inflata*, but the specimens are not very good. This species and *Astarte major* are in fact, so far as I can see, the only forms mentioned by Dr. Feistmantel which really indicate an alliance between the *Umia* fauna and that of middle jurassic beds.

It is scarcely necessary to point out how very strongly the evidence of the *Trigonia* confirms Dr. Waagen's views of the upper jurassic affinities of the *Umia* group; as the *Cephalopoda* of the group are confined to the lowest beds, it is quite possible that the upper portion, containing the plants, may be of wealden or even neocomian age. The only marine fossil known to be found above the plant-beds is *Tr. Smeei* (I am not sure whether *Tr. ventricosa* accompanies it or not) and there is no reason why this species should not range into lower cretaceous. This position would quite accord with the circumstances of the *Umia* group being immediately succeeded by strata with upper neocomian *Cephalopoda*, if the former pass up into the latter. It is not, however, clear from Dr. Stoliczka's notes whether this is the case or not.

Of course all that has been said as to the impossibility of determining the horizon of beds from the affinities of a very small percentage of selected fossils is equally applicable to Dr. Feistmantel's remarks on the Katrol and Chári beds.¹ Is the occurrence of a single middle jurassic *Monotis* in the Katrol group, and of a liassic species of the same genus in the Chári beds of any weight when compared with the mass of evidence afforded by the cephalopod fauna?² In the sub-divisions of the Chári group alone there are thirty-nine *Cephalopoda*, either identical with European species, or so closely allied that Dr. Waagen, who is not addicted to uniting species, does not separate them. We are actually asked to doubt this evidence on the strength of a single species of *Monotis*. It would be as reasonable to suppose the Chári group cretaceous because it contains two *Terebratulæ*, which have been referred to the cretaceous species *T. sellæ* and *T. biphicata*.

Again as to *Parasuchus*, the identification of the Maleri flora with that of Jabalpur was hazardous, to say the least, but whether the identification was correct, or whether, as now appears probable, the Maleri beds are older than the Jabalpur group, either they are not triassic, or Dr. Feistmantel's own identification of them is wrong. Why then, in order to make out the Cutch beds older, does he write³ of "*Parasuchus*, a vertebra of that Crocodilian fossil which is looked upon as Triassic, and which occurs frequently with the Jabalpur flora near Maleri, which latter is identical with our Kach flora." Mr. Lydekker⁴ has since shewn that the generic identity of the Cutch and Maleri fossils is uncertain.

Before concluding these remarks on the Cutch beds there is one more point to which I have to take exception, and that is the classing together of the *Umia*

¹ Rec. G. S. I., vol. IX., p. 116.

² Pal. Ind., Ser., vol. IX, pp. 226-230.

³ Rec. G. S. I., vol. IX., p. 116. See also Pal. Ind., Ser. II, pt. 2, p. 57.

⁴ Rec. G. S. I., vol. X, p. 35.

and Katrol groups of Cutch, without, so far as I can see, any sufficient evidence being produced in justification of the change.

In the introduction¹ to the description of the flora of the Golapilli beds (Rájmahál) referring to *Trigonia ventricosa* and to its occurrence in some beds at Innaparazpilli near Coconada, Dr. Feistmantel writes, "The same form occurs in the upper beds (Umia and Katrol)," and a few lines further on, "As now the upper beds in Kach, with that *Trigonia*, are called *Umia* and *Katrol* (both being thus joined by the most common fossils), these *Trigonia* beds near Innaparazpili may be taken to represent both these groups in Kach." On the next page² the Sriparmatur and Ragavapuram beds are said to be overlaid by Katrol and Umia deposits, and in a table showing the supposed relations of various upper Gondwána groups, the higher beds in Cutch (Kach) are classed together as Umia-Katrol. There are, I may add, several points of correlation in this table which are, to say the least, open to question.

Trigonia ventricosa may be found in the Katrol group, although I can find no previous mention of its occurrence, but it is certainly not common, and it is misleading to say that the Umia and Katrol groups "are joined by the most common fossils." Altogether, forty-five species of *Cephalopoda* have been found in the two subdivisions of the Katrol group and ten in the Umia, and of these only one, *Belemnites Kunkotensis*, is common³ to the two, another being indicated as doubtfully identical.⁴ So far as I am aware, too, the characteristic bivalves of the Umia group do not occur in the Katrol beds. I think Dr. Feistmantel may have expressed himself ill, and that what he really means is that the plant-remains of the two groups are similar, but it is scarcely correct to speak of these as the most common fossils, for they are rarer than marine fossils in the Umia group, and in the whole Katrol subdivision they have hitherto only been detected in one locality.

KOTA-MALERI BEDS.—On these I have very little to say. They were at first classed by Dr. Feistmantel as Jabalpur beds⁵ on account of the occurrence of two Jabalpur species of Conifers, *Palissya Jabalpurensis* and *Araucarites Cutchensis*, and a supposed lower portion was separated and considered equivalent to the Rájmahál group⁶ on account of the occurrence of *Palissya conferta* and *Chirolepis Muensteri*. This view was adopted at first by Mr. Hughes and Mr. King on the evidence of the plants. It is instructive, and it affords an example of the risk of placing too much dependence on fossil-plants, to find that the discovery of additional species in the Kota-Maleri beds has shown that the rocks contain a mixture of

¹ Pal. Ind., Ser. II, pt. 3, p. 164.

² l. c., p. 165.

³ Pal. Ind., Ser. IX, p. 4. At p. 232, however, Dr. Waagen says that not a single species passes from the Katrol into the Umia group. The doubtful identification is *B. claviger*.

⁴ l. c., p. 7.

⁵ Rec. G. S. I., Vol. IX, pp. 86, 134-135.

⁶ Rec. G. S. I., l. c., Pal. Ind., Ser. II., pp. 57, 165, 190. See also Mr. King, Rec. G. S. I., Vol. X, p. 61, &c. Subsequently Dr. Feistmantel modified his statements about the absolute separation of the groups in the Gondwána region, Rec. G. S. I., X, p. 29, but the mischief was done.

Jabalpur and Rájmahál forms, and that the separation of the beds with Rájmahál fossils is untenable.

In two or three cases the reptilian fossils of the Kota-Maleri beds are quoted by Dr. Feistmantel as liassic. Thus, in one instance¹ he writes, "Remains of *Lepidotus* and of *Hyperodapedon* have also been found in the *Ceratodus* beds indicating the same liassic formation;" and again,² "In the Wardha field . . . the same flora (Jabalpur) is associated with liassic terrestrial animals." The only liassic forms are fish; the sole animal of probably terrestrial habits hitherto described³ is *Hyperodapedon*, which in Europe is exclusively triassic, and the affinities of both *Parasuchus*⁴ and *Ceratodus* are unmistakeably triassic. It is, in fact, the association of characteristically triassic types with equally marked liassic genera in the same group of rocks which adds so greatly to the interest of the Kota-Maleri beds,⁵ and the circumstance that these remains are clearly insufficient to enable the geological age of the beds to be accurately determined shows how cautious we should be in attaching weight to the far less characteristic plant evidence.

RÁJMAHÁL GROUP.—In proceeding to the Rájmahál flora I should, perhaps, commence by saying that Dr. Feistmantel may possibly be correct in considering it liassic, but I think he fails to prove his case, and I cannot but believe that the emphatic assertion and re-assertion that the flora is liassic, on every page of the "Palæontologia Indica,"⁶ from title to colophon, is a mistake. I think the arguments in favour of the flora of the Umia group of Cutch being middle jurassic are certainly stronger than the instances brought forward to prove the liassic affinities of the Rájmaháls, and yet⁷ the apparent connexion in the first instance is misleading.

I shall not attempt to go into the question of the Rájmahál flora in detail. I simply take Dr. Feistmantel's own data, as fully given in the "Palæontologia Indica,"⁸ and I find that fifteen species are said to be closely allied to rhætic fossil

¹ Rec. G. S. I., Vol. IX, p. 135.

² Pal. Ind., Ser. II, p. 56.

³ Q. J. G. S., Vol. XXV, 1869, p. 138. It may be thought that I am descending into trifling details, and that it is unfair to quote what may, after all, be misprints. I can only say that I am merely taking a few instances of mistakes almost at random, and I could give many more. Whether liassic is a misprint for triassic, or whether the mistake is due to carelessness, the effect is the same. I should probably have omitted the paragraph but for finding the following statement made by Dr. Feistmantel about the Kota-Maleri fossils in the last number of the "Palæontologia Indica" containing the description of the Jabalpur Flora, Ser. XI, pt. 2, p. 102-22, "We know, for instance, that *Hyperodapedon* in England is a Triassic Dinosaurian, and so is *Belodon* in Germany."

I regret having to call attention to such mistakes, but it is not fair to the other members of the Survey, who have been mercilessly criticised by Dr. Feistmantel, that errors like this should be left unnoticed. It must be remembered that Dr. Feistmantel has always had proofs of his papers, and consequently is fully responsible for any errors in them.

⁴ Q. J. G. S., Vol. XXXI, 1875, p. 430, &c.

⁵ Rec. G. S. I., Vol. IX, p. 84.—Pal. Ind. Ser. IV, pt. 2, p. 17.

⁶ Ser. II, pts. 2, 3; see also Rec. G. S. I., Vols. IX, X, *passim*.

⁷ Rec. G. S. I., Vol. IX, p. 82.

⁸ Ser. II, pp. 143, 187, &c.

plants and only three to liassic, two out of these three having equally close rhætic affinities. Omitting these two, the rhætic affinities of the Rájmahál flora are shewn to be in proportion to the liassic affinities as thirteen to one, or in other words, the connection with the European lias is only one-thirteenth of the affinity to the rhætic. Not a single identical species is known with certainty to occur in either case,¹ the only suggested identification, that of *Pterophyllum propinquum*, being, as Dr. Feistmantel himself notices, founded on a fragment too imperfect for accurate determination.

It is perfectly true that besides the liassic and rhætic forms, there are shown to be four or five Rájmahál species² related to middle jurassic (lower oolitic) plants, one being identical; and this argument, which is indicated, though not so clearly as could be desired, in the 4th paragraph on p. 160, is the only one of any value urged. At the bottom of the page, however, Dr. Feistmantel says, "We have, therefore, fossil plants which exhibit Liassic character, with some forms having their representatives in the Rhætic." Everywhere, on page after page, the liassic relations of the flora are insisted upon, and it is only when, turning from assertions to facts, the reader commences to examine the relations of the plants in detail, he finds liassic affinities are scarcely shewn to exist. Of the style of argument adopted, I will quote only one instance. On one page³ the genus *Palissya* is said to be known only from rhætic strata; on the opposite page, near the bottom, is the following line, "CONIFERÆ. *Palissya indica*, Fstm., indicating lias."

The real fact, so far as I can judge from Dr. Feistmantel's data, is that the Rájmahál flora has very little similarity to any known fossil flora in Europe. There is a certain generic connexion with certain lower and middle mesozoic plants, but there is absolutely less similarity to the rather poor flora of the lias than there is to the rhætic or even to the oolitic flora. To label the flora as characteristically lias is, I think, a mistake, and will lead to error.

It is so difficult to hunt out anything through Dr. Feistmantel's multifarious notes and descriptions, of which I trust I may be pardoned for saying that the arrangement might be improved with advantage, that I may have overlooked some reference to the relations between the Rájmahál flora and that of the Uitenhage formation in South Africa, but I have not found any notice of this important fact.⁴ The latter flora occurs in the Geelhoutboom beds or wood bed

¹ At p. 160 several liassic plants are enunciated, *Alethopteris Whitbyensis*, *Pecopteris Nebbensis*, *Thinnfeldia rhomboidalis*, &c., and are said to have near analogies in the Rájmahál group. In the "General table of the fossil flora of the Rájmahál group with relations and analogous forms in other formations," pp. 143-148, and at p. 155 in the list of characteristic plant-remains of the group and their age, it is shown in several instances that the affinities of the Rájmahál species with rhætic plants are closer than with the liassic forms subsequently mentioned.

² *Sphenopteris arguta*, *Pterophyllum fissum*, *Williamsonia* sp., *Araucarites macropterus* and perhaps *Hymenophyllites Bunburyanus*.

³ Pal. Ind., Ser. II, p. 154.

⁴ Tate: Q. J. G. S. 1867, Vol. XXIII, pp. 144, 169, &c. I think the connexion has been briefly noticed by Dr. Feistmantel in the "Neues Jahrbuch," but I am unable to find the passage.

series, which underlie the rocks with upper and middle jurassic fossils on Sundays and Zwartkops rivers, and overlie the Enon conglomerate at the base of the Uitenhage formation, to which succeeds in descending order the Karoo series, classed by Tate as triassic, but probably, in part at least, older. The following plants have been described¹ :—

FILICES.

Pecopteris Atherstonei } both nearly allied to *P. (Alethopteris)*
P. Rubidgei } *Indica*, a Rájmahál form.
P. Africana.
Asplenites (or *Pecopteris*) *lobata*, a Rájmahál species.
Sphenopteris antipodum.
Cyclopteris Jenkinsiana.

CYCADACEÆ.

Palæozamia (*Otozamites*) *recta*.
P. (Podozamites) Morrisi.
P. Rubidgei.
P.? *Africana*.

CONIFERÆ.

Arthrotaxites (*Echinoistrobus*) *Indicus*?² closely allied to a Rájmahál plant, if not identical.

LOWER GONDWÁNA.—PANCHET GROUP.—If the age of the Panchet group were determined by the plant fossils, there can be no question, on the strength of the evidence adduced by Dr. Feistmantel,³ that these beds would have to be classed as rhætic. Of the four species identified, two are said to be European rhætic forms, a third is closely allied to a rhætic species, and the fourth, *Schizoneura Gondwanensis*, though most closely allied to a lower triassic species, belongs to a rhætic genus. Now this evidence, so far as it goes, having regard only to the percentage of similar forms, and not to the total number of species, is stronger than that on which the Umia beds of Cutch were classed as lower oolitic, and the Damuda series as lower triassic, and incomparably superior to that which is said to distinguish the Rájmahál flora as liassic. Why, therefore, does Dr. Feistmantel in this case class the Panchets as “representative of the highest trias (Kenper)”?

The reason is not far to seek. It has already been noticed that the relations of the Rájmahál flora, so far as that flora has any real connexion with European fossil plants, is rhætic rather than jurassic. But the Panchet flora is also rhætic. Now, between the Panchets and Rájmaháls there is by far the widest break in the

¹ l. c. See also p. 148.

² This species has been re-named by Dr. Feistmantel *Rajmahalensis*. No valid reason, so far as I am aware, has been assigned for the change.

³ Rec. G. S. I., Vol. IX, p. 65. Two forms of *Glossopteris* have since been added, R. c. G. S. I., Vol. X, p. 139, but they do not much affect the argument, as they are said to pass into higher beds.

whole Gondwána system, a break amply shown to exist both on palæontological grounds, and, which is of far greater importance, on geological evidence. With the Panchet beds the reign of ferns and *Equisetaceæ* appears to end, the flora of the upper beds (I am simply taking Dr. Feistmantel's own data) consists very largely of gymnosperms, ferns being relatively less numerous, although still abundant. The geological break is unmistakable. In the coal-fields of the Damuda valley, the Panchets, together with the underlying groups, were upheaved and disturbed before the intrusion of the trap dykes believed, on good evidence, to be of Rájmahál age. Now, to admit that the beds above, and those below this huge break, both belong to one of the smallest groups of the European series would be tantamount to confessing the fact that fossil plants are worthless for the determination of minor divisions, consequently the upper beds are pushed up into the lias with which they have little or no connexion, and the lower groups fitted into one of the established grooves in the trias with which they are equally unconnected. I quite admit the temptation, to every one who is fond of order and who prefers certainty to doubt, to adopt this plan of pigeon-holing strata, if I may so term the process; it is neat and compact, and it has only one objection, which is, that it is radically false and unscientific. That the affinities of the Panchet fauna and flora are, on the whole, triassic, is not new, and the only additional evidence obtained of late years, such as the further examination of the reptilian fauna of South Africa,¹ and the classification of the *Labyrinthodontia*,² whilst by no means conflicting with the original opinion that the Panchet beds might be lower mesozoic or upper palæozoic, is a warning against an attempt at correlating these Indian formations too closely with the European sub-divisions. To define the relations of the Panchet group by substituting Keuper for trias is, I believe, a retrograde step in the present position of our knowledge; the gain is merely a change in names, not in acquaintance with facts, and the nomenclature is more likely to need subsequent correction.

DAMUDA SERIES: *Mángli beds*.—Before entering into the question of the relations of the Damuda flora, I must devote a few words to the Mángli beds. I believe that Dr. Feistmantel's expressed opinions as to the relations of these beds are untenable. The question is partly palæontological, partly geological, and, as the first alone has been treated by Dr. Feistmantel, I shall deal with it before the other. The opinions from which I dissent will be found at length³ in a "Note on *Estheria* in the Gondwána Formation," and I would beg any one who wishes fully to appreciate the importance of the facts I am about to state, before going farther, to read Dr. Feistmantel's remarks. He concludes that "the Mángli beds cannot belong to the Damuda series at all, and that they are rather to be considered as the uppermost continuation of the Panchet group." This opinion, it must be remembered, is opposed to my own⁴ after I had examined the

¹ Owen: Q. J. G. S., Vol. XXXII, p. 352, and Brit. Mus. Cat., S. Af. Rept.

² Repts. Brit. As. 1874, pp. 150., &c.

³ Rec. G. S. I., Vol. X, p. 26.

⁴ Mem. G. S. I., Vol. IX, p. 326.

rocks, and to that of Mr. Hughes,¹ although the latter was founded on a thorough and exhaustive survey of the whole country.

The plant evidence is very slight, and I do not understand Dr. Feistmantel to attach much importance to it. The only recognizable fragments consist of two stems, and these are so poorly preserved that Sir C. Bunbury,² who had, I believe, quite as good specimens as those examined by Dr. Feistmantel, was uncertain whether the one was a lycopod (*Knorria*) or a conifer, and whether the other should be referred to *Stigmaria* or to a fern. Dr. Feistmantel may be correct in saying that he is "convinced" that the first is a conifer and belongs to *Palissya*, but it may fairly be questioned whether the suggested identification of such fragments with the rhætic *P. Brauni* is of any importance. The other specimen Dr. Feistmantel says "is certainly a fern stem" and very similar to those described from the rhætic beds in Bavaria. This may be quite correct, but the value of the evidence is so small that it may safely be disregarded until very much more is known of fossil fern stems. As to the supposed *Palissya*, a stem, which is not uncommon locally in the ironstone shales of the Damuda beds, has a striking resemblance to the Mángli fossil; so far as I can judge (the question is one for a botanist, and my knowledge of the science is insufficient for my opinion to have any weight), the resemblance is as close as that of the Mángli stem to *Palissya Brauni*. As, moreover, it has been shewn by Heer³ that fragments of the Permian *Voltzia Hungarica*, in which the leaves are preserved, but the leaf-scars (*Zapfen*) are wanting, can scarcely be distinguished from the rhætic *Palissya Brauni*, it may be doubted if the leaf-scars alone, all that is preserved in the Mángli stems, are sufficient for specific identification. The plant evidence, from such fragments, may be safely dismissed as worthless.

The animals of the Mángli beds are of more importance. They consist of *Estheria* and a Labyrinthodont, *Brachyops laticeps*. Of the former Dr. Feistmantel says⁴—

"There are certainly two forms, a larger and a smaller one—

"a.—*Estheria Mangaliensis*, Jones This is the larger form, which Mr. Jones described first from Mángli . . . On some specimens *E. Mangaliensis* is only represented, while on some others it is mixed with the other smaller form, and still, on some others, this latter only is predominant.

"Jones gave several figures which all indicate the larger form *E. Mangaliensis* J. As to the age Mr. Jones considered these beds, for certain reasons, as Rhætic, and now Professor Geinitz describes the same species from beds of the same age in South America.

"b.—*Estheria comp. minuta* var. *Brodieana*, Jones. This form was not described; it is, however, as frequent as the larger one. From the size and form, and from the structure of the shell, they can safely be taken as very closely allied to *Estheria minuta* var. *Brodieana*, Jones, which, as Mr. Jones indicated so distinctly and exhaustively, is characteristic of the rhætic beds."

"This smaller form the Mángli beds have in common with the Panchet group."

¹ Mem. G. S. I., Vol. XIII, p. 71.

² Q. J. G. S., Vol. XVII, 1861, p. 340.

³ Verh. K. K. Geol. Reichsanst. Wien., No. 2, 1877, p. 43.

⁴ Rec. G. S. I., Vol. X, p. 27.

The following extract¹ from Professor Rupert Jones' own paper "on Fossil *Estheria* and their Distribution" will show whether the smaller form was or was not described:—

"7. *Estheria Mangaliensis*, Jones. At Mangali in Central India, about sixty miles south of Nagpur, the Rev. Messrs. S. Hislop and R. Hunter discovered in 1853 a fossiliferous, brick red, laminated sandstone, which contains remains of plants, of Ganoid fishes, and of Labyrinthodont reptiles (*Brachyops laticeps*, Owen.) and wide-spread, thin layers of *Estheria*. These, though of various sizes and somewhat different outlines, are all referable to one species, conditions of growth being sufficient, in my opinion, to account for all the seeming varieties. This *Estheria* (*E. Mangaliensis*) is not without close alliances (so far as the carapace is concerned) to other species, fossil and recent, as is generally the case; but it gives no direct evidence as to its geological horizon.

". . . . Another locality for *Estheria* in Indian strata of approximately the same age has been found by Mr. W. T. Blanford near Pachet in Bengal. Dr. T. Oldham kindly sent me a sample of this *Estherian* shale; but I cannot say more than that this *Estheria* seems to be the same as the smaller specimens from Mangali."

I have distinguished three sentences with italics, and it is quite unnecessary to show how completely they disprove Dr. Feistmantel's supposition that the smaller form was not described, and that Professor Rupert Jones considered the beds rhætic. Dr. Feistmantel was probably not acquainted with Professor Rupert Jones' paper in the "Quarterly Journal," but in the monograph of *Estheria* published by the Palæontographical Society, and quoted by Dr. Feistmantel, the dimensions of several specimens of *E. Mangaliensis* are given, varying in their longest diameter from less than $\frac{1\frac{1}{2}}{12}$ to $\frac{4}{12}$ of an inch, and instead of there being on the plates "several figures, which all indicate the larger form," of the five views of the whole carapace, one only, fig. 16, represents the larger form, three figures, 21, 22, and 23 represent the smaller form, and one figure, 20, is intermediate in size. All these figures are on the same scale, being magnified six diameters, so that the distinction is manifest at a glance.

I ought to add that both Mr. Hislop³ and I⁴ fell into the error of supposing that two species of *Estheria* occurred at Mangli, before Professor Rupert Jones' description was published, and I find that I repeated the suggestion that there were more than one in a later paper.⁵ It is only fair to myself to say that the last paper was not originally intended for publication, and that it was printed in my absence. Moreover, the subject was only mentioned incidentally in a brief geological description of the locality, and I did not, like Dr. Feistmantel, attempt to discuss the relations of the species.

I do not think there can be any question that the *Estheria* examined by both Professor Rupert Jones and Dr. Feistmantel were identical. Both had some of the original specimens obtained by Mr. Hislop; and those collected by

¹ Q. J. G. S., 1863, Vol. XIX, p. 149.

² Pal. Soc., Foss. Esth., Pl. II.

³ Jour. Bombay Br. R. A. S., Vol. VI, pp. 201, 203.

⁴ Mem. G. S. I., Vol. III, p. 134.

⁵ Rec. G. S. I., Vol. I, p. 65. The words were "*Estherias* (of two species apparently) abound."

myself, and now in the Survey collection, came, I believe, from the same quarry. These *Estheriæ* are extremely abundant at the spot, and both the larger and smaller forms are found in profusion.

Of course, I do not mean for a moment to assert that Professor Rupert Jones is infallible. He may be wrong, and Dr. Feistmantel may be right. But considering that there is scarcely any constant difference in size or form between *Estheria minuta* var. *Brodiana*, and the smaller variety of *E. Mangaliensis*, and that the only essential distinction appears to be in the microscopical structure of the carapace, I am myself disposed to think it more probable that Professor Rupert Jones was right in the identification of the small Mángli *Estheria*, because he had studied the whole genus, and figured the various forms with their microscopical structure, whilst Dr. Feistmantel had only a few forms for comparison, and has omitted all mention of microscopical structure, which, I believe, he has not examined with anything more powerful than a pocket lens.

The statement that "Mr. Jones considered these beds, for certain reasons, as rhætic" may be compared with the extract from Mr. Jones' own paper. It is true that he suggested that the beds might be triassic or rhætic, but the statement was never made in the unqualified manner in which it is quoted.¹ Mr. Hislop, certainly, in his last letters,² as quoted by Dr. Feistmantel, expressed an opinion that the Mángli beds "lie above the coal strata," and in one sense he was right, for the Kámthi beds, to which, as I will show presently, the Mángli beds clearly belong, are higher than the Barákars, the coal-bearing group of the Central Provinces, but in the very same sentence he writes of the Korhádi shales, which are Talchir beds, and consequently at the base of the whole Gondwána system, being also above the Umret coal (Barákar). It is scarcely fair to Mr. Hislop, and it is most unfair to Mr. Hughes, to quote the views of the former, expressed before any thorough examination of the country had been made, in opposition to those of Mr. Hughes, who has mapped the whole district closely.

With regard to *Brachiops laticeps*, Dr. Feistmantel is quite correct in saying that Labyrinthodonts occur in the European Keuper, and, he might have added, in the rhætic and jurassic also. The nearest allies of *Brachiops*³ are *Micropholis Stowii* from the Beaufort beds of the Karoo series in South Africa, *Rhinosaurus Jasikovii* from the Russian oolite and *Bothriceps Australis* from unknown rocks in Australia. The first named is more closely allied than the others, and it occurs in the same beds with the *Dicynodontia*, *Theriodontia* and other South African fossil reptiles. The connexion is of small value as an indication of age, but important as showing the relations of the Indian Gondwána fauna with the ancient life of South Africa and Australia.

¹ At p. 81 of the monograph Professor Jones certainly says that he ventures still to regard these beds as belonging to the rhætic formation, but in the table shewing distribution opposite p. 114, referring to the species classed as rhætic, he writes, "The adoption of this stage for the *Estheriæ* from India and America is merely provisional; they may be triassic."

² Q. J. G. S., Vol. XX, 1864, p. 232.

³ Q. J. G. S., 1859, p. 642,—Repts. Brit. As. 1874, pp. 150, 160.

The Estheria from Kawarsa.—Having thus far treated the purely palæontological affinities of the Mángli beds, I will, before proceeding to the geological argument, advert to the Kawarsa *Estheria*. After a few notes on the *Estheria* from the Panchets, which Dr. Feistmantel says “is certainly identical with the smaller form of *Estheria* in the Mángli beds, mentioned as *Estheria minuta*, var. *Brodieana*, Jon.”¹ he proceeds to discuss the occurrence of apparently the same crustacean at Kawarsa. The following are extracts from the account given²:—

“The Kawarsa beds occur near the southern³ margin of the basin, and Mr. Hughes speaks of them as several hundred feet from the base of the series. They have yielded some broken plant-remains and *Estheria*.

“a.—An *Equisetaceous* stalk, pretty distinct; it belongs to that group of forms which generally are termed *Phyllothea*.

“b.—A fragment of an oblongly lanceolate leaflet, with marked ribs, which might belong to *Schizoneura*, Schimp.

“c.—Some broken specimens of *Glossopteris* occur very rarely in comparison with those so richly represented leaves at Nagpur, and elsewhere in the Damudas; and I have no doubt that these beds, near Kawarsa, are younger than all the real Damudas, including the Kámthi Raniganj group.

“To this indication now is to be added the occurrence of *Estheria*, which is certainly identical with that in the Panchet group, the state of preservation and the size and form⁴ being identical; and is therefore to be considered as very likely *Estheria minuta* var. *Brodieana* Jon.

“From the occurrence of the *Estheria*, an animal fossil which is still so frequent in the Mángli beds and in the Panchet group, and from the scarcity of plants altogether⁵ and from the state of the rock, it would, I think, follow that the locality at Kawarsa is scarcely to be considered as representative of any group of the real Damuda beds, the fossils of which are everywhere so different from those both of the Mángli and the Kawarsa beds?”

Contrast with the last passage and with the above list of plants the following list⁶ of the same plants from Kawarsa as supplied by Dr. Feistmantel himself to Mr. Hughes, and published by the latter:—

“1. *Phyllothea Indica*, Bunb. Established by Bunbury as an Indian type. It is one of the *Equisetaceæ* of the genus *Calamites* (Suckow) and reminds one of *Calamites*

¹ Dr. Feistmantel adds, “I compared specimens from both localities, and I could not find any difference.” This had been done before by Professor Rupert Jones (Q. J. G. S., Vol. XIX, p. 149), Mr. Hislop (Jour. Bom. Br. R. A. S., Vol. VI, p. 201) and myself (Mem. G. S. I., Vol. III, p. 134, with the same result, but, as was pointed out by Professor Jones, the condition of the Panchet species is such as to prevent the identification from being certain.

² Rec. G. S. I., Vol. X, p. 28.

³ South-west margin would be more correct.

⁴ The value of size and form in determining species of *Estheria* will have been seen from the details already given as to the differences between *E. Mangaliensis* and *E. minuta* var. *Brodieana*. I do not understand how the “state of preservation” in fossils can be employed as a means of identification.

⁵ This is another argument which could not be used by any one having a knowledge of the rocks in the field, for the Kámthi group is remarkable for the paucity of organic remains. Surely, too, Mr. Hughes and I, who examined the beds at Kawarsa, are better qualified to judge of the “state of the rock” and its bearing upon the relations of the beds than Dr. Feistmantel is from the examination of half a dozen cabinet specimens derived from a single bed.

⁶ Mem. G. S. I., Vol. XIII, p. 70.

arenaceus, Jäger. It might perhaps be considered as only the stalk of *Schizoneura* Schimp.

"2. *Schizoneura*, Schimp. fragments.

"3. *Glossopteris Indica*, Schimp. (*Glossopteris Browniana*, var. *Indica*, Bgt.), a piece of a large leaf with large reticulations.

"4. *Glossopteris Browniana*, var. *Australasica*, Bgt. Some smaller leaves than the above may be determined as being of this species."

Surely the species quoted are well known and characteristic Damuda fossils, but even if the specific identity be not certainly determined, what can be the meaning of the statement that the fossils of "the real Damuda beds are everywhere so different" from those of the Kawarsa beds? All of the species named are found either in the typical Kámthi beds near Nagpur, or in the Damuda rocks of Bengal.

In another paper Dr. Feistmantel writes thus,¹ adverting to the occurrence of *Glossopteris* fronds in a fragmentary condition amongst the Panchet beds—

"This manner of preservation resembles that in the Kawarsa beds of the Chanda district, where *Glossopteris* occurs also in a very fragmentary state, and again associated with *Estheria* (the form as in the Panchets and in the Mángli beds). In my note on the *Estheria* beds in India I have already pointed this out, and I repeat again that the Kawarsa beds very likely are on the horizon of the Panchets in Bengal.

This can only mean that the fragmentary occurrence of *Glossopteris* fronds indicates contemporaneous deposition! Fragments of leaves are the rule in all plant-bearing formations, so far as my experience goes, but no collector brings them away when he can obtain more perfect specimens.

The value of the observation as to the rarity of occurrence of *Glossopteris* at Kawarsa will be best appreciated in connexion with the fact that Dr. Feistmantel has never visited the locality and has seen only about half a dozen specimens.

I am sorry to be obliged to expose in this manner the value of the arguments put forward, but leaving them without answer has already done mischief, and it is necessary to show the kind of data upon which Dr. Feistmantel bases his conclusions in this case. His reason for arguing that the Kawarsa beds are not Damudas are probably the following. Learning that Dr. Geinitz had found an *Estheria*, apparently identical with *E. Mangaliensis*, in some beds said to be of rhætic age in America, Dr. Feistmantel appears to have concluded rather hastily that the Mángli beds were of the same age, and as this view received some support from Professor Rupert Jones' original remarks, it was accepted. The occurrence of the Mángli *Estheria* with characteristically Damuda plants at Kawarsa was a difficulty, and hence the very curious arguments which were employed to make out that these Damuda plants prove that the beds in which they occur are not of Damuda age. Of course the circumstance that one form of the Mángli *Estheria* occurs with Damuda plants about 30 miles away at Kawarsa is of vastly greater importance in determining the relations of the Mángli beds than the existence of the same *Estheria* with rhætic plants in South America.

¹ Rec. G. S. I., Vol. X, p. 139.

There is one more point to notice. I cannot agree with Dr. Feistmantel's opinion that "*Estheria* has hitherto been neglected in India in the discrimination of horizons,"¹ and I think this is a fair instance of the manner in which Dr. Feistmantel often writes of all who have preceded him. Whether he *intends* in this case to charge his colleagues and Mr. Hislop with neglect or not is not the point at issue. I do not accuse him of *intentional* injustice; I simply question the accuracy of his statement. All the fossil species of *Estheria* hitherto found in India have been described and figured, and if this has not been done "in India" surely Anglo-Indians are not to be blamed because they send fossils for description to competent naturalists in Europe. Every known discovery of *Estheria* in the Gondwana beds, either by Mr. Hislop or the Survey, has been noticed in print, nor is there a single occurrence noted by Dr. Feistmantel which had not been previously recorded. Why, then, are we charged with neglect? The evidence I have given above will enable any one to compare Dr. Feistmantel's use of *Estheria* with the previous "neglect," and to determine which course is most in accordance with scientific truth.

Geological evidence.—Thus far I have treated the question of the palæontological relations of the Mángli beds, my object being to shew how untenable Dr. Feistmantel's views are. But it must not be forgotten that these views were opposed to Mr. Hughes' and my own, founded upon geological evidence. As my own examination of the rocks was only preliminary, I depend chiefly upon Mr. Hughes, who has examined the whole of the Wardha coal-field in detail. I have accepted Mr. Hughes' views when they differ from my own in the case of the Maleri beds, so it is not merely because our opinions coincide as to the Mángli beds that I quote my colleague's determinations, but solely because he had fuller opportunities for coming to a decided conclusion.

Mr. Hughes' ² views as to the beds of Mángli are, I think, perfectly clear. He does not express any doubt as to the position of the strata; he places them amongst the typical Kámthi beds, and estimates that they are about 700 feet above the base of the group. It is true that no higher beds than the Mángli beds are seen in the immediate neighbourhood, because the Deccan traps rest unconformably on the Gondwanas close by, but there are higher Kámthi beds elsewhere. A few pages farther³ the occurrence of red argillaceous shales, like those of Mángli, is noted north-east of Balár hill, near Wún, and Mr. Hughes remarks that as they should not be more than 400 feet above the coal-measures, the horizon assigned to the Mángli beds is probably not too low. This, of course, implies that the Mángli beds are probably the equivalents of those seen near Balár hill. Now, the Kawarsa and Punwat beds are nearly on the strike of these beds north-east of Balár hill, and therefore presumably on nearly the same horizon as the Mángli beds, the rock containing *Estheria* at Punwat⁴ resembling the Mángli shale in mineral character. But above the beds at Kawarsa and Punwat are all the sandstones of Malargarh hill, which are characteristically Kámthi. There is no part of the Wardha field

¹ Rec. G. S. I., Vol. X, p. 30.

² Mem. G. S. I., Vol. XIII, p. 71.

³ L. c., p. 75.

⁴ L. c., p. 77.

in which the geology is clearer than in this ground, and there cannot, I think, be any reasonable doubt that, so far from the Kawarsa beds being higher than the Kámthis, they are clearly intercalated in the group, and are much nearer to the base than to the top. I have examined the ground more than once, and my preliminary map agrees with Mr. Hughes' finished survey. I cannot see how there can be any reasonable question that both the Kawarsa beds and the Mangli beds are typical Kámthis. I am aware that this is not stated so emphatically and clearly by Mr. Hughes, but he could scarcely have anticipated that his opinions would be disputed in the publications of the Survey by one who had never seen the ground, and who depended upon such palæontological arguments as those I have just exposed.

Flora of the Damuda series.—I have already in the first part of this paper dealt at sufficient length with the evidence brought forward by Dr. Feistmantel to shew that the Damuda flora is characteristically mesozoic. That the generic relations of this flora are mesozoic rather than palæozoic; that there is an almost total want in the Damudas of the characteristic forms found in such abundance in the European coal-measures; that *Lepidodendron*, *Sigillaria* and a host of other carboniferous types are absent; and that their place is taken by plants more nearly affined to mesozoic forms, have been admitted by everybody, but precisely the same is true of the flora intercalated with beds containing typical carboniferous marine fossils in Australia. The fact that the Damuda flora consists mainly of ferns and *Equisetaceæ*, and the very subordinate part played in these beds by cycads and conifers are palæozoic characters, although they are quite insufficient alone to prove that the beds are palæozoic. My object in the present instance, as in my last paper, is not to prove the Damudas palæozoic, but to vindicate Dr. Oldham and his colleagues of the Survey from Dr. Feistmantel's attacks, and to show that their opinion, that the Damuda flora has little or no connexion with any known European fossil flora, and that the former is much more nearly related to the coal flora of Australia, is more correct than Dr. Feistmantel's. The estimate of the relations of the Damuda flora depends upon two distinct questions—

1. Is the Damuda flora more nearly affined to any European fossil flora than it is to that found in certain Australian beds?
2. What are the relations, geological and palæontological, of those Australian beds?

I have already stated the facts as they were known to me,¹ but I find I have omitted several items of importance in relation to the Australian beds. In consequence of these omissions, Dr. Feistmantel's reply appears stronger than it really is.

I write under correction, and with a full sense that I am dealing with a subject of which I am not a master, but merely a student, but still I think that the plan adopted by Dr. Feistmantel to prove the Damudas mesozoic involves a fatal error. From the whole of the Damuda flora he takes a plant here and a plant there, shows that it is related, now to a triassic, now to a rhætic, now to a juras-

¹ Rec. G. S. I., Vol. IX, pp. 82, &c.

sic European species, and then he points out that the sum of these relations exceeds the connexion which exists between the Damuda flora and that found in the Australian beds. But the Australian flora with which comparison is made is confined to one group of rocks and has been but imperfectly investigated; whilst against the identifications and assimilations with this one poor assemblage of plants, consisting of only about twenty fairly known species, there is urged every possible connection which can be detected between Damuda plants and those found in all the various widely exposed floras of Europe between cretaceous and permian. Even under these conditions, I doubt if Dr. Feistmantel has proved his case. That the Damuda flora has a mesozoic facies is no new discovery; the fact has been admitted, I believe, by every writer on the subject, whatever his opinions as to the age of the beds, and the same is notoriously the case with the Australian Newcastle flora, but I do not think that either the age or homotaxis of a group of rocks can be determined by comparing the flora with several distinct assemblages of plants of varying age, so well as by showing the connexion with the species found in one defined group.

Relations of Damuda flora to European trias and Australian beds respectively.—To show the views I have to answer I make a few extracts from Dr. Feistmantel's later papers, those written since my own appeared—

"The affinities of our Damuda flora with that of the mesozoic epoch and especially of the triassic formation are overwhelming."¹

"We have in all the special collections unmistakable evidence for the supposition of M. Bunbury as to the mesozoic, and, as I add, triassic age of the Damuda flora.

"Already in the old collections from Raniganj there were proofs enough!"²

[That is before the discovery of the Karharbári fossils. The remainder of the sentence has already been discussed.]

"The Damuda flora exhibits itself quite decidedly as mesozoic and most naturally as of triassic age."³

"We know that the Panchet group overlies immediately the Raniganj group, which itself is Lower Triassic."⁴

"I have also shown that the Damuda are Lower Triassic."⁵

And in various tables showing the relations of the Gondwána groups to European strata the Damuda series is always classed by Dr. Feistmantel in accordance with his original determination as the equivalent of the Bunter (lower trias).⁶

Some Karharbári plants are doubtless allied to Bunter species, and Dr. Feistmantel was perfectly right in including these forms in the Damuda flora, because

¹ Rec. G. S. I., Vol. IX, p. 117.

² *Ib.*, p. 119.

³ *Ib.*, p. 121.

⁴ Rec. G. S. I., Vol. X, p. 28.

⁵ Pal. Ind., Ser. II, 2, p. 160.

⁶ Rec. G. S. I., Vol. IX, p. 125; Pal. Ind., Ser. XI, p. 2, Geol. Mag. Dec. 2, III, 1876, p. 491. Leon. Gein. Neues Jahrb. 1877, p. 159

the Karharbári beds had always been classed by the Survey as lower Damudas until the plant-remains were examined. I shall, however, show presently that the Karharbári beds must be separated from the true Damudas. One of the extracts I have above quoted shows that Dr. Feistmantel considers that the relations of the Damuda flora to that of the European trias is well marked, independently of the Karharbári plants.

It is as well here before turning to the connexion between the Damudas and the Australian rocks to recapitulate the succession in descending order of the New South Wales beds as given by Mr. Clarke and Mr. Wilkinson.¹ Dr. Feistmantel's classification I will dispose of hereafter. The following is the succession:—

1. Wyanamatta beds.
2. Hawkesbury beds.
3. Upper coal measures, or Newcastle, Wollongong, and Bowenfels series.
4. Lower coal measures associated with marine beds.
5. Lepidodendron beds (Devonian).

Dr. Feistmantel in the paper to which I am especially replying admits a certain connection between the Damuda flora and that of the upper coal measures of Australia. Yet he writes—in this case referring to the upper coal measures No. 3—

“Thus it seems that the evidence of a connection with the Australian coal measures is very weak, while the fossils enumerated as common with European Trias are unmistakeably identical.”

It is only fair to say that the most of Dr. Feistmantel's remarks on the dissimilarity of the Damuda and Australian floras refer to the lower coal measures of Australia, and to these I will proceed presently. I am however, I believe, stating his views fairly when I conclude that he considers the connexion between the Damuda flora and that of the European lower triassic rocks stronger than that which unites the Damudas with the upper coal measures of Australia. To show how far this view is tenable, I place in parallel columns (1) Dr. Feistmantel's own list of Damuda plants,³ *minus* the Karharbári forms which are not known to occur in true Damuda rocks, (2) Schimper's list of Bunter (lower triassic) plants,⁴ and (3) the list of Australian species from the upper coal measures obtained by adding together the names given by McCoy, Morris, and Dana.⁵

¹ Q. J. G. S., 1861, Vol. XVII, p. 358. “Mines and Mineral Statistics of New South Wales,” Sydney, 1875, p. 128.

² Rec. G. S. I., Vol. IX, p. 122. Only one species, *Voltzia heterophylla*, has been shown to be specifically identical with a European plant. *Voltzia acutifolia* is, I understand, a synonym of *V. heterophylla*, and the connexion in other species is merely generic.

³ Rec. G. S. I., Vol. IX, pp. 119-121, and subsequent additions.

⁴ Traité de Paléontologie Végétale, Vol. III, p. 645.

⁵ Q. J. G. S., 1861, p. 359.

BUNTER (Europe).

EQUISETACEÆ.

*Equisetum Mougeotii.**E. Brogniarti.***Schizoneura paradoxa.*

FILICES.

*Neuropteris grandifolium.**N. Voltzii.**N. intermedium.**N. elegans.**Pecopteris Sultziana.**Crematopteris typica.**Anomopteris Mougeotii.**(Sphalopteris, Mougeotii)*
stem.*(Chelopteris Vogesiaca)*
stem.*(C. Voltzii)* stem.*(C. micropeltis)* stem.*(Cyatopteris tessellata)*
stem.*(Bathopteris Lesangeana)*
stem.*(Caulopteris ? Maraschi-*
niana) stem.*(C. ? Laliana)* stem.*(C. Festariana)* stem.

CYCADEACEÆ.

*Pterophyllum Hogardi.**Zamites Vogesiacus.*

DAMUDA.

EQUISETACEÆ.

Schizoneura Gondwanensis.Sphenophyllum speciosum (v.*
trizygia).†*Phyllothea Indica.*†*Vertebraria Indica.*

FILICES.

Actinopteris Bengalensis.†*Sphenopteris polymorpha.**S. (Dicksonia), sp.*†*Alethopteris Lindleyana.*†*A. conf. Whitbyensis.**A. phegopteroides.**Teniopteris (Angiopteridium),*
sp.*T. (Macrotaniopteris) dana-*
*oides.**T. (M.) Feddeni.**Palæovittaria Kurzi.*†*Glossopteris Browniana.*†*G. Indica.*†*G. communis.*†*G. angustifolia.*†*G. leptoneura.*†*G. musæfolia.*†*G. stricta.*†*G. several other species.**Sagenopteris pedunculata.**S. polyphylla.**Gangamopteris Whittiana.**G. Hughesi.**Belemnopteris Wood-Masoni-*
ana.

CYCADEACEÆ.

†*Noeggerathia Hislopi.**N. , sp.**Pterophyllum Burdwancense.*NEWCASTLE BEDS (Aus-
tralia).

ALGÆ?

*(Anarthrocanna.)**(Cystoserites.)**(Confervites tenella.)*

EQUISETACEÆ.

†*Phyllothea Australis.**(P. ramosa.)**(P. Hookeri.)*†*Vertebraria Australis.*

FILICES.

Sphenopteris lobifolia.†*S. alata, var. exilis.**S. hastata.**S. Germani.**S. plumosa.**S. flexuosa.*†*Alethopteris Australis.**Pecopteris ? odontopteroides.**Otopteris ovata.*†*Glossopteris Browniana.*†*G. linearis.*†*G. ampla.*†*G. reticulum.*†*G. elongata.**G. cordata.*†*G. several other species.**Gangamopteris (Cyclopteris)*
angustifolia.

CYCADEACEÆ.

Noeggerathia (Zeugophyl-
lites) elongata.†*N. spatulata.**N. media.*

CONIFERÆ.	CONIFERÆ.	CONIFERÆ.
<i>Voltzia heterophylla.</i> (<i>V. acutifolia</i>).	(<i>Palissy</i> ? sp.), stem.	Some undetermined forms.
<i>Albertia latifolia.</i>		
<i>A. Brauni.</i>		
<i>A. elliptica.</i>		
<i>A. speciosa.</i>		
<i>A. Schauerothiana.</i>		
<i>Taxites</i> ? <i>Massalongi.</i>		
<i>T.</i> ? <i>Vicentinus.</i>		
MONOCOTYLEDONES.		
<i>Yuccites Vogesiacus.</i>		
(<i>Spirangium regulare</i> — fruit only.)		
<i>Æthophyllum speciosum.</i>		
<i>Æ. stipulare.</i>		
<i>Æ. Foetterleanum.</i>		

In the above lists names placed between parentheses may be neglected; they are either too obscure for recognition, or synonymous, or else founded solely on parts of the plant, such as stems or the fruit alone, which cannot be fairly compared. Species representing each other in the Bunter and Damuda flora are marked with an asterisk (*), allied forms in the Damuda and Australian flora with a dagger (†). It is possible that some of the Australian species of *Sphenopteris* and *Glossopteris* should have been omitted, as they are not sufficiently defined for their relations to be known,¹ but I wish to place the whole evidence, so far as I am acquainted with it, before my readers. Doubtless, too, some species have been added to the Bunter flora since Schimper's work was published, and some rectifications may have been introduced.

The above lists, moreover, are not in all cases fairly comparable, the Bunter flora of Europe and the Damuda flora of India having been far better explored than that of Australia. Moreover, we may be sure that any point of resemblance, however slight, between the Bunter and the Damuda flora has been noticed by Dr. Feistmantel, whilst it is far from equally certain that the full connexion between the Damuda and Australian floras has been traced by an equally competent judge. I have classed all the species of *Glossopteris* in the Damuda series and the Newcastle beds, with one exception, as allied to each other, and I believe I am fully justified in doing so, but possibly one or two forms may not be so nearly related as I suppose. But in this subject I am *ultra crepidum*. I only take up a matter with which I have an imperfect acquaintance because it appears to me unfair to the Survey that only one side of an argument should be stated, and because, in self defence, I am bound to show that I really have stronger reasons for objecting to Dr. Feistmantel's views than he is willing to admit.

¹ I have omitted a form called *Austrella rigida*, founded on what appears to me to be nothing but rootlets, perhaps of *Vertebraria*. Precisely similar bodies abound in Damuda beds, but are, of course, worthless for comparison.

I take the Bunter flora for comparison because Dr. Feistmantel has repeatedly stated that the Damudas are of lower triassic age, but I may add, that were I to give the lists of known plants from Keuper or rhætic, (the flora of the Muschelkalk is too poor for comparison,) the result would be the same. There are a few allied forms in each of these subdivisions,¹ and probably there are more in the rhætic than in the trias. There are also certain Damuda forms such as *Phyllothea Indica*, *Sagenopteris*, *Alethopteris Lindleyana* and *A. conf. Whitbyensis* which are much closer to jurassic European forms than to triassic, and it may be remembered that many European palæontologists long classed the Damudas as oolitic. In short, so far from its being the fact that there is a distinct connexion between the Damuda flora and that found in European lower triassic rocks, the truth is really that there is not so strong a resemblance between Damuda and Bunter plants as there is between Damuda and jurassic. On the other hand, I do not see how any one can look over the list given above without seeing the very marked similarity between the Damuda flora and that of the Newcastle beds in Australia. So marked is this, that even if the Karharbári forms be included in the Damuda flora as Dr. Feistmantel has done, it still appears to me that the former is more closely allied to the Australian than to the Bunter flora.

The conclusion at which I arrive is, that instead of the evidence which connects the Damuda formation with the Australian carboniferous rocks being about equal to that between the Damudas and European trias, as I at first thought, the former connexion is more marked than the latter.

The relations of the lower Australian beds.—I pass on to the second question. The third point on which, in Dr. Feistmantel's opinion, my conclusions were "rather premature"² related to the lower Australian coal strata, and, as he puts his thesis, "The analogy with the flora of the lower coal strata in Australia is comparatively weak".³ I do not think this is an answer to my argument, because I never insisted upon the affinity between the Damuda flora and that of the lower coal measures of Australia. What I did show was⁴ that the connexion between the various groups of the coal-bearing series in Australia, from the Wyanamatta beds to the lower coal measures, (excluding, of course, the *Lepidodendron* beds,) was exactly the same as that on the strength of which Dr. Feistmantel had just argued that the whole of the lower Gondwânas were triassic; and if the argument were applied to the Indian beds, it was equally valid in justifying the classification of all the Australian rocks below the Hawkesbury beds (and I might even have included the Hawkesbury and Wyanamatta

¹ The only Keuper plants which have any marked relations to Damuda species, so far as I am aware, are some forms of *Pecopteris* or *Alethopteris* allied to *A. Whitbyensis*, and *Noeggerathia Vogesiaca* (*Macropterygium Brannii*), the latter alone being of any importance. Perhaps there may be a slight similarity between some of the Keuper species of *Pterophyllum* and *P. Burdwanense*. It should be remembered that only one specimen of *Pterophyllum Burdwanense*, and one of *Noeggerathia* cf. *Vogesiaca* have yet been found in Damuda beds.

² Rec. G. S. I., Vol. IX, p. 117.

³ And again, p. 121, "c What is the analogy of our Damuda series with the lower coal measures in Australia?"

⁴ *Ib.* p. 83.

beds) as carboniferous. I then shewed the connexion between the flora of the upper and lower coal measures in Australia taken together, and that of the Damuda beds.

The above would really be a reply to all that is stated in the sentence above quoted. Dr. Feistmantel has not answered me. He has merely traversed an argument which differs materially from that I used. But in the course of his remarks he enters into the real question at issue and makes several atements which, if correct, would have some weight as opposed to my opinion. I shall, therefore, shew how far these statements are in accordance with the facts made known by various Australian geologists.

I have already twice had to refer to Dr. Feistmantel's classification of the Australian rocks. Here it is¹—

	{ Beds in Tasmania, Queensland, Victoria. }	{ Without New South Wales. }	
Upper coal measures.	{ Clarence river. Wyanamatta beds. Hawkesbury beds. Bowenfels. Upper beds in Newcastle. }		{ No animals. }
Lower coal measures.	{ Beds with marine plants intercalated with plant-beds. Especially Stony Creek, Rix. Ck., Greta, Mnt. Wingen, &c. Again marine beds. }		
Culm series.	{ Smith Creek. Port Stefens. }	{ Lower carboniferous plants with carboniferous animals. }	
Devonian.	Goonoo-goonoo. Plant-remains only.		

This Dr. Feistmantel states² is “the succession of the several strata of the Australian coal formation, as Mr. Clarke communicated it to me in a late paper, and as it is to be found in his ‘Remarks.’” It is to be regretted that Dr. Feistmantel has not given a reference to the Rev. Mr. Clarke's paper, because there is, so far as I can see, nothing in the “remarks” which can be quoted to justify the classification adopted, and the union of the Wyanamatta, Hawkesbury and Newcastle beds into one subdivision as upper coal measures, and their separation from the lower coal measures are so entirely opposed to all that Mr. Clarke has written on the subject, that it is to be hoped Dr. Feistmantel will either publish Mr. Clarke's own words, or admit that he has arranged the section to suit his own views. The beds in Tasmania, Queensland, &c., have nothing to do with the main question and only tend to distract attention from the typical sequence in New South Wales. In the printed paper of Mr. Clarke's,³ to which we have all hitherto referred for the classification of the Australian (New South Wales) plant-bearing rocks, they are thus arranged—

- | | |
|----------------------|---------------------------------|
| 1. Wyanamatta beds. | 3. Coal seams of Newcastle, &c. |
| 2. Hawkesbury rocks. | 4. Lower carboniferous rocks. |

¹ Rec. G. S. I., Vol. IX, p. 123.

² l. c.

³ Q. J. G. S., 1861, Vol. XVII, pp. 357, 358, &c.

The last being the "culm" and "Devonian" beds of Dr. Feistmantel's series, with which I have no present concern. No. 3 includes both the upper beds in Newcastle and Dr. Feistmantel's "lower coal measures." In the "Remarks"¹ the *Lepidodendron* beds are noticed under the heading of Middle Palæozoic, all the coal measures of Newcastle are classed in the upper Palæozoic, together with the "lower coal measures" of Dr. Feistmantel, while the Wyanamatta and Hawkesbury beds are treated apart from the others under the heading of Mesozoic or Secondary Formations. Take the following extracts² from the "Notes on the Upper Palæozoic Beds" and compare them with Dr. Feistmantel's classification:—

"As far as some of the plants are concerned, it may be admitted that they are in an unsatisfactory condition at present; but the balance in favour of a carboniferous age for the *Glossopteris* beds is, to my mind, conclusive."

The *Glossopteris* beds include both the upper (Newcastle) coal measures and the lower coal seams with marine bands. Again³—

"So far, then, the question about the age of some of the Australian coal must be considered as settled; and if, as in Illawarra, the coal beds overlie the marine beds, as they do also in the Fingal district of Tasmania, it would appear that all these separate occurrences belong to one thick series, in which marine beds and fresh-water beds interpolate each other. But assuredly in that case the arrangement adopted must express the order as follows:—

"1. Upper coal measures.

"2. Upper marine beds.

"3. Lower coal measures.

"4. Lower marine beds."⁴

I cannot see how Mr. Clarke can be quoted to justify the removal of the upper coal measures from the palæozoic series in the face of such evidence as this. I beg to call attention to the fact that Dr. Feistmantel always gives his own version of Mr. Clarke's views, whereas I quote Mr. Clarke's published words.

Mr. Clarke may have changed his views (I have no reason to believe he has); he may, like myself, have been guided by Dr. Feistmantel's statement⁵ that there is a radical difference between the flora of the upper (Newcastle, Bowenfels) and lower (Stony Creek, &c.) coal measures in Australia. I accepted Dr. Feistmantel's opinion as that of an expert, and was immediately quoted by him as evidence,⁶ part of my sentence quoted by him being omitted so as to

¹ Mines and Mineral Statistics of New South Wales, &c., Sydney, 1875, pp. 161...191.

² Clarke, l. c., p. 178.

³ *Ib.*, p. 179.

⁴ Mr. C. S. Wilkinson, the Government Geologist, writes thus in the same work, page 128,—
"The several divisions of the upper palæozoic series have been named after the localities where they are found to be most typically developed. In descending order they are as follows:—

"Wyanamatta series.

"Hawkesbury series.

"Upper coal measures of Newcastle, Wollongong and Bowenfels series.

"Upper marine beds.

"Lower coal measures.

"Lower marine beds.

"Lepidodendron beds."

Rec. G. S. I., Vol. IX, pp. 70, 71, 121, &c.

⁶ I said, Rec. G. S. I., Vol. IX, p. 83, "Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both, although, from specimens which Dr. Feistmantel has shown

make it appear that my opinion was founded on my own observations, and not on his. I very greatly regret to say that further experience of Dr. Feistmantel's statements has produced a sceptical spirit, especially when they are in opposition to the evidence of other observers, and I now refuse to admit there is any important distinction between the flora of the upper and lower Australian coal measures until Dr. Feistmantel produces evidence instead of assertions. I think it probable Mr. Clarke will show equal caution. When Dr. Feistmantel's evidence appears, it will remain to be seen how far he has established his thesis. If I appear to be harsh in my judgment, I would refer to the facts I have already pointed out as to the evidence on the strength of which Dr. Feistmantel has over and over again asserted that the Rájmahál flora is liassic, and to his statements about the Mángli beds and the *Lamellibranchiata* of the Umia group.

The original evidence as to the connection between the upper (Newcastle) coal measures and the lower beds of Stony Creek was, that below "grits and conglomerates full of *Pachydomi*, *Spiriferi*, *Orthoceratites*, large *Conulariæ*, *Asteridæ*, &c., a bed of shale was reached in which are impressions of *Noeggerathia* (or *Zeugophyllites*), *Glossopteris* (or *Sagenopteris*) and other plants, such as *Cyclopteris*, that look as much like jurassic as any that are so called."¹ In the "Transactions of the Royal Society of Victoria, Vol. VI" (I have not access to the original² at present), sections were given by Mr. Clarke from Stony Creek showing the occurrence of *Glossopteris*, *Phyllothea* and *Noeggerathia* in the beds below those containing the marine fossils. Take, again, the following extract from the notes by Mr. E. C. Wilkinson, Government Geologist³:—

"The collection of fossils from near West Maitland, Greta and Anvil Creek includes *Spiriferæ*, *Conulariæ*, *Inocerami*, *Productæ*, *Fenestellæ*, *Bellerophon*, crinoidal stems, &c., obtained from the upper marine beds 350 feet above the Anvil Creek coal seam, from which seam I collected the specimens now shown, containing the *Phyllothea* and *Glossopteris Browniana*. Immediately below this coal are the lower marine beds represented by the specimens of *Spiriferæ*, *Conulariæ*, *Bellerophon*, *Pachydumus*, *Orthoceras*, *Euomphalus*, *Fenestella*, a new species of Starfish, *Chæletes radians*, &c., from Stony Creek, Harper's Hill, Ravensfield, and Singleton. This suite of fossils is especially interesting, as showing not only the range through the coal series of the *Glossopteris* and *Phyllothea*, plants so abundant in the upper coal measures of Wollongong, Lithgow Valley and Newcastle, but also the association of those plants with the marine fauna of the lower coal measures, thus affording evidence, agreeing with that of the previously mentioned fishes, as to the upper palæozoic age of the New South Wales coal measures"

In the same work, "Mines and Mineral Statistics of New South Wales," several detailed sections are given. In section No. 1, p. 206, bed No. 5 in descending order contains "large fossils, *Fenestella*, *Inoceramus*, *Conularia*, &c.;" No. 19 is said to be "full of *Glossopteris*, *Phyllothea*, and leaves of ? *Noeggerathia*;" No. 24

(misprinted *shewed*) to me there appears to be a considerable distinction in the flora." Dr. Feistmantel quoted this paragraph (Records, Vol. IX, p. 122), but omitted the words in italics, thus making the statement appear to rest on my authority instead of on his own. This, moreover, was emphasized by the concluding portion of the sentence being placed in italics.

¹ Q. J. G. S., 1861, Vol. XVII, p. 360.

² The volume is wanting in the Survey library.

³ Mines and Mineral Statistics, p. 132.

is said to be "full of large *Glossopteris* fronds, &c., same as bed No. 12." Again, at p. 226, in a section of some coal seams and the accompanying shales. The uppermost bed, a coarse conglomerate, is said to be "full of palæozoic fossil fauna, *Conularia*, *Orthoceras*, *Producta*, *Spirifera*, *Inocerami*, *Crinoidea*, &c.," whilst 6 feet lower down is "shale full of *Glossopteris*, *Phyllothea* and *Noeggerathia*."

So far, then, we have evidence of four species of plants in the "lower coal measures." These species are—

- 1.—*Glossopteris Browniana*, admitted by all to be identical with the species from the upper coal measures.
- 2.—*Phyllothea*.
- 3.—*Noeggerathia*.
- 4.—*Teniopteris* near *T. Eckardi* (this is inserted on Dr. Feistmantel's authority).

Now, where is the evidence that the plants called *Phyllothea* and *Noeggerathia* from the lower beds are distinct from those in the upper? I have already quoted McCoy's identification of the *Phyllothea*, apparently from the lower beds of Queensland, with *P. Australis*, the species found in the upper coal measures of Newcastle, &c. Dr. Feistmantel's evidence as to the distinction of the lower coal measures' flora, so far as he has hitherto supplied any facts, amounts to this, that he has seen a *Teniopteris* from the lower beds which he has not seen from the upper. He may have more evidence, but that produced is certainly not sufficient to justify the rejection of the opinions given by Australian geologists.

The rest of the evidence brought forward by Dr. Feistmantel need not detain us long. He says (I am obliged to re-quote part of the paragraph)²—

"As to 3 and 4, of which the first are the upper coal measures of Newcastle, Mr. Blanford himself says, 'Nos. 3 and 4 appear to be connected by the presence of *Glossopteris Browniana* in both,'³ although there appears to be a considerable distinction in the flora;⁴ and I would add, No. 3 does not contain any animals,⁴ while in No. 4 marine animals are found abundantly."⁵

And again⁵—

"a.—The upper portion is marked by a flora, which is abundant. Nos. 1, 2, 3 of Mr. Blanford's list must be referred to this; they contain no marine fossils to indicate a connection with the lower portion.

"b.—The lower coal measures are marked by two marine faunas of, as generally taken, a carboniferous age, which separate distinctly these from the upper beds. The flora is, as both Mr. Clarke and Mr. Daintree state, only rare."⁶

Now, this is one of those points on which my ideas are so diametrically opposed to Dr. Feistmantel's that I can only suppose, either that our notions of elemen-

¹ *Ante*, p. 112.

² Rec. G. S. I., Vol. IX, p. 122.

³ See footnote 6, *ante*, p. 138, for the original form of the sentence here quoted and the portion suppressed by Dr. Feistmantel.

⁴ This is incorrect of course; a fish has been obtained from the bed.

⁵ l. c., p. 123.

⁶ No reference is given, and the statement is quite opposed to all the evidence; see the quotations from the sections in "Mineral and Mineral Statistics" just given, where shales of the lower beds are said to be full of *Glossopteris*, *Phyllothea* and *Noeggerathia*. The section quoted (No. 1, opposite p. 206) is given by Mr. Clarke himself.

tary geological evidence are distinct, or else that Dr. Feistmantel does not mean what his words convey. It is superfluous to point out that if distinction of age were proved by the presence or absence of marine fossils, the *Glossopteris* beds of the lower Australian coal measures must be of a different age from the fossiliferous marine beds with which they are intercalated, because no marine fossils are found in the beds containing the *Glossopteris*. If the lower plant-beds are not different in age from the marine fossiliferous rocks with which they are interstratified, neither can the upper coal measures be shown to be of distinct age from the lower on account of not containing marine fossils.

I have one more extract to make. I hope that it will be understood that in these remarks I am merely taking a few instances from Dr. Feistmantel's papers; I could easily add others. The extract is the following¹:—

"In the last publication, 'Mines and Minerals of New South Wales,' there is a supplementary report by Mr. John Mackenzie on the New South Wales coal fields, in which, on section *b*,² is a sketch section from Newcastle to Port Booral, about thirty miles long. In this the difference in the fossil remains of the upper and lower portions of the coal measures is plainly indicated, and also that the upper portion and lower portion are, besides all the differences, slightly discordant."

The fossil differences are, that in the lower portion several marine carboniferous genera occur, and in the upper portion only plants, and that those plants do not include the genus *Noeggerathia* (the plant known by this name is, however, found elsewhere in the same beds) and do include some forms not found in the lower beds. *Phyllothea* and *Glossopteris* are quoted from both. So far good; now about the discordance. I fear I shall have some difficulty in convincing my readers without showing them the book, but the truth is that all the evidence of stratigraphical relations in the figure quoted consists in coal seams being indicated in three distinct parts of the section, those to the right having a higher dip than those in the middle, and the latter again higher than those to the left. This is all; there is not, so far as I can see, the smallest indication of unconformity, which is, I presume, what is meant by the beds being said to be discordant, since it is the only way in which a distinction between the different groups could be shown in the section. How far Dr. Feistmantel is correct in supposing that the upper and lower coal measures are "slightly discordant" may be judged by the following extracts from the work in which the section cited appears.

Mr. Clarke himself says³—

"The fact that the coal beds overlie or interpolate the marine beds in what is called 'conformable order' ought to be considered a satisfactory conclusion that no break, such as ought to exist under other circumstances, does exist. . . ."

There can, I think, be no question that Mr. Clarke here refers to both upper and lower coal measures; the sentence would be void of meaning otherwise, and in the previous sentence he refers to the occurrence of ganoid fishes, which

¹ Rec. G. S. I., Vol. IX, p. 124.

³ Mines and Mineral Statistics, p. 166.

² Evidently a misprint for *section 6*.

have, so far as I know, only been found in the upper coal measures and overlying groups.

The next two quotations from the same work are from the reports by Mr. Wilkinson, the Government Geologist, and are perfectly clear. He says—¹

“The upper coal measures in the western district are about 480 feet thick, resting conformably on the marine beds of the lower coal measures.”

And again²—

“These marine beds are conformable to the overlying plant-beds of the upper coal measures, but rest unconformably on the upturned edges of Devonian strata.”

Mr. Clarke, too, in a footnote, p. 170, quotes a report of Mr. Daintree's on the country between Newcastle and Stony Creek, in which the following passage occurs:—“Neither does there seem any reason why Mr. Clarke should not place the Newcastle coal seams (his No. 3, carboniferous group,) in the upper portion of this Stony Creek group, no known unconformity existing.” The Stony Creek group is, of course, the same as the “lower coal measures,” with marine fossils. Mr. Daintree's opinion is of importance, for he appears to have gone from Victoria to examine Mr. Clarke's sections, the accuracy of which was doubted by the South Australian geologists, and to have confirmed Mr. Clarke's views.

These extracts are, I fear, tedious, but they are too important to be omitted, because they shew that Australian geologists do not admit the existence of any break between the upper and lower coal measures.

The characteristically mesozoic Taniopteris Daintreei.—So far I have confined myself to the beds in New South Wales. As I stated at the outset, to mix up with them the beds of Tasmania, Queensland and Victoria tends to confuse. But as these latter beds are adduced as evidence of mesozoic age, it is as well to examine the proof. In the case of the Queensland beds, the age may at once be considered as established on trustworthy evidence,³ the plant layers with *Taniopteris* and other forms being above strata containing jurassic marine fossils, whilst the beds with *Glossopteris* occur at a lower horizon associated with Palæozoic mollusca, &c., and underlying the jurassic deposits unconformably. Now, the upper Queensland beds⁴ are said to contain two species of plants which occur in other parts of Australia. One of these is *Taniopteris Daintreei*,⁵ and the clue afforded

¹ p. 130.

² p. 132.

³ Q. J. G. S., vol. XXVIII, 1872, pp. 325, &c.

⁴ Rec. G. S. I., IX, pp. 123, 124.

⁵ The importance which Dr. Feistmantel attaches to this fossil is noteworthy. Thus, at p. 136 he writes, “The same *Phyllothea Australis*, McCoy, is also known from Victoria, together with *Taniopteris Daintreei*, McCoy, which latter in Queensland is considered as characteristic of the mesozoic (upper) coal beds.” Again, p. 138, “McCoy described it (*Gangamopteris*) first from some rocks in Victoria, where no marine fossils occur, but where *Taniopteris Daintreei*, McCoy, is found, which latter in Queensland is considered as characteristic of the mesozoic beds there. With these also *Phyllothea Australis*, McCoy, occurred in Victoria.” Again, at the bottom of the same page, “This *Gangamopteris* is in Victoria found in certainly mesozoic rocks, being associated with *Taniopteris Daintreei*, McCoy, which is characteristic of mesozoic rocks in Queensland;” and finally

by this fossil to the determination of the age of the beds in Victoria, and the reflected light thus cast upon Indian rocks through *Gangamopteris angustifolia* and *Phyllothea*, which are associated with *Teniopteris Daintreei* in Victoria are frequently noticed by Dr. Feistmantel. *Teniopteris Daintreei* is also noticed as occurring with *Pecopteris Australis* in Victoria, whilst in Tasmania *Pecopteris Australis* and *Glossopteris* occur together.¹ All this is quoted from McCoy,² with one slight omission; the specific name of the *Glossopteris* is not mentioned, although McCoy states that it is *G. Browniana*, and as this is admitted to be a palæozoic species, its occurrence with the *Pecopteris* would neutralize the importance of the *Teniopteris* in any case.

But I cannot understand how Dr. Feistmantel overlooked another remark of Professor McCoy's on the next page, in which it is pointed out that the Queensland specimen called *Teniopteris Daintreei* is probably different from that of Victoria. Here is the brief description of each form—

"*Teniopteris Daintreei*, McCoy, from Victoria.³ *General character*.—Frond, simple or pinnate, long, narrow with a thick strong midrib, from which the veins extend nearly at right angles to the lateral edges, either once or twice forked or simple.

"*Teniopteris Daintreei*, McCoy, and Carruthers, from Queensland.⁴ Frond, simple (?), broad linear; midrib somewhat thick; veins leaving it at an acute angle, then passing out at right angles to the margin, once or twice dichotomously divided."

I have italicised portions of the above, and I can only add that so far as I can, without any special botanical knowledge, give an opinion, it appears to me that, judging from the figures in the two works quoted, the two so-called *Teniopteris Daintreei* of Victoria and Queensland must be very well marked and distinct species. It is scarcely conceivable that they can be specifically identical.

It is true that *Pecopteris odontopteroides* is said to be common to the Queensland jurassic strata and to the Wyanamatta and Newcastle beds of New South Wales. But Carruthers himself points out distinctions in shape between his figures of the Queensland form and Morris' representation of the New South Wales fern, although he believes both to belong to the same species.⁵ As there is a strong probability that the Queensland and New South Wales beds are really of different age, it is to be hoped that this question will be re-investigated.

The remainder of the evidence as to the fossil flora of Victoria tends to show that this flora cannot, in all probability, be much newer than the Newcastle beds of Australia. *Phyllothea* and *Gangamopteris angustifolia* occur in both. It

p. 143, "I must still once more state that the Australian *Gangamopteris* is from mesozoic strata in Victoria, together with *Teniopteris Daintreei*, McCoy."

¹ Rec. G. S. I., vol. IX, pp. 121, 122, 123.

² Prodrôme, Pal. Vict., Dec. II, pl. XIV.

³ Prodrôme, Pal. Vict. Dec. II, p. 15.

⁴ Q. J. G. S., Vol. XXVIII, 1872, p. 355.

⁵ This fern has been referred by Morris and Carruthers to *Pecopteris*, by McCoy to *Gleichenites*, by Dr. Feistmantel to *Thinnfeldia*, and by a Belgian writer, Fr. Crepin, to *Otopteris*—Bull. Soc. Roy. Belg., vol. XXXIX, p. 258. Can all have examined the same fossil? The figures appear to me to show considerable variation.

would, therefore, be of some importance if the beds of Victoria were really connected with the jurassic plant-beds of Queensland. As it is, there is really no evidence, except the plants, to show that the Victoria beds are mesozoic.

Ganoid fish of Australian beds.—Before leaving the Australian beds I have to call attention to the very important evidence as to the age of the whole series in New South Wales, afforded by the remains of fish. I have already shown that Dr. Feistmantel is mistaken in saying that the upper coal measures of Australia contain no animals, and that he has himself mentioned those animals in another page. The known forms consist of ganoid fishes, and the following have been described and figured:—

Palæoniscus antipodeus. From Wyanamatta beds.

Chleithrolepis granulatus. Cockatoo beds between Wyanamatta and Hawkesbury.

Myriolepis Clarkei.

Urosthene Australis. Newcastle beds.

The question of the relations of these fish has been thoroughly stated by Sir P. Egerton,¹ certainly one of the highest living authorities, and he concludes thus²—

“With regard to the larger question of geological period, there appears to be sufficient evidence to stamp these remains as belonging to the palæozoic age.”

He proceeds to give the range of the nearest allies in Europe, and to show that representatives of all the forms named are associated in the greatest numbers in permian strata (Kupferscheifer). It would be easy to quote authorities for the much greater importance to be attached to fish remains as evidence of age than to plants, all I have to do now is to point out that the evidence of the fish tends to place the whole of the New South Wales rocks from the Wyanamatta beds downwards in the palæozoic epoch. It is quite true that in his later papers Mr. Clarke has classed the Wyanamatta and Hawkesbury beds as lower mesozoic, and probably he is right in doing so, but the plant evidence in favour of this view is of precisely the same nature as that on the strength of which *Glossopteris Browniana* and its carboniferous associates were long classed as jurassic. Probably the Wyanamatta and Hawkesbury beds are of the same age as some of the rocks in Victoria, and they may be approximately of triassic age, or they may be partly permian or intermediate between permian and trias, but their horizon is not ascertained with accuracy.

Glossopteris beds in South Africa.—There is another locality in the southern hemisphere, where, apparently, representatives of the Damuda formation may be traced. Dr. Feistmantel's principal object being to trace the connexion between the Damuda plants and the mesozoic flora of Europe, he has alluded but briefly to the African rocks.³ They are important because although very

¹ Q. J. G. S., 1863, vol. XX, p. 1.

² p. 4.

³ Rec. G. S. I., Vol. IX, p. 71.

little is known of their flora, the little that has been ascertained indicates a very close connexion with that of Indian and Australian beds.

The plants occur in the upper groups, the Stormberg and Beaufort beds of the Karoo series; the latter being the principal Dicynodont beds, and containing the following species, which have been described by Mr. Tate¹:—

Glossopteris Browniana (the specific identification may perhaps be questioned, but the species is doubtless closely allied).

G. Sutherlandi, a narrow form like *G. angustifolia* and *G. leptoneura*.

Rubidgea Mackayi, very closely allied to the Damuda *Palæovittaria*, if not generically identical.

Dictyopteris simplex; this has been shown by Dr. Feistmantel² to be a *Glossopteris* allied to some Indian (Damuda) species.

Some equisetaceous stems referred to *Phyllothea*.³

There is here a remarkable similarity to the Damuda flora. Only ferns and *Equisetaceæ* are known; all the ferns belong to the simple-leaved forms so abundant in the Damuda beds, and three out of the five plants belong to *Glossopteris*. There is nothing approaching to this amount of similarity in any known European fossil flora, and the close connection between this ancient association of plants in Indian, South African and Australian strata tends strongly to support the idea of a former land connection between these countries, a probability which is strengthened in the case of South Africa, by the representation of certain Ráj-mahál forms in the jurassic Uitenhage series, and by close alliances between jurassic and cretaceous marine fossils belonging in some cases, in all probability, to littoral forms. The relations of the Panchet *Dicynodon* and the Mángli *Brachyops* to African forms are also worthy of notice.

KARHARBÁRI GROUP.—A few words are necessary as to the reasons for distinguishing this group. The coal-bearing rocks of the Karharbári coal field were originally classed as Barákar (Lower Damuda) by the Survey,⁴ but after the fossils associated with the coal had been determined by Dr. Feistmantel,⁵ the

¹ Q. J. G. S., 1867, p. 140.

² Rec. G. S. I., Vol. IX, p. 73.

³ Besides these Dr. Feistmantel notices, Rec. G. S. I., Vol. IX, page 73, the occurrence of a species probably belonging to *Gangamopteris*, "described by Mr. Tate, from the Karoo beds (triassic) in South Africa as *Cyclopteris Jenkinsiana*." A reference to the original description (Q. J. G. S., 1867, Vol. XXIII, p. 146) will show that Dr. Feistmantel is mistaken, as this plant was described from the higher Uitenhage series, classed as jurassic, and not from the Karoo beds. I am, to some extent, responsible for the error, as I edited the paper, but I was not then aware of the amount of revision required by Dr. Feistmantel's papers.

⁴ Mem. G. S. I., Vol. VII, p. 209.

⁵ I regret to be obliged to call attention to the manner in which Dr. Feistmantel has repeatedly mentioned the dates at which these and other fossils were discovered (see especially Rec. G. S. I., Vol. IX, p. 119; Geol. Mag. 1876, p. 489, footnote 12), in order to cast discredit upon myself and others, and to cause it to be believed that these plants were known at a time when I had stated that they were undiscovered. Dr. Feistmantel has omitted to state that the fossils mentioned had been packed away in drawers and boxes, and with, I believe, one exception, had not been identified by any one. Of the exception no notice had appeared in print; the specimen had not been exhibited, and its existence was not known to the Survey generally.

occurrence in great abundance of certain forms, such as *Voltzia* and *Neuropteris*, which had never been noticed in true Damuda rocks, made me suspect that there must be some distinction in the beds, and this view was strengthened by further examination of the flora. In July last Mr. Hughes and I paid a short visit to Karharbári, and by the assistance of Mr. Whitty, Superintendent of the East Indian Railway Co.'s collieries, we were enabled to see much of the ground in a short time. We came to the conclusion that there was an important distinction between the Karharbári coal and that of the Damuda series (both Barákar and Raniganj), the laminated structure so peculiarly characteristic of Damuda coal being almost absent in the Karharbári seams, and, moreover, the conglomeratic beds associated with the Karharbári strata contained subangular fragments, whereas the Barákar pebble beds contain usually none but well-rounded pebbles. The topmost beds in the little field had rather the aspect of Barákars, and some indications appeared to suggest that these beds overlapped the Karharbári group unconformably, but this was not by any means clearly determined. Still, considering the great similarity between all the coal-bearing beds, the distinctions noticed all tended to bear out the separation of the group first suggested by the fossils.

The following is a list of the fossil plants determined by Dr. Feistmantel:—

EQUISETACEÆ—

- Vertebraria Indica*, very rare.
- Schizoneura* sp., near *Equisetum Meriani*.

FILICES—

- Neuropteris valida*.
- Gangamopteris cyclopteroides*.
- G. angustifolia*, and two other species of *Gangamopteris*.
- Glossopteris decipiens*.
- G. communis*.
- Sagenopteris Stoliczka*.

CYCADEACEÆ—

- Glossozamites Stoliczka*.
- Noeggeruthia* (*Zamia*?) *Hislopi*, var.
- N.* (*Z.*?), sp.
- A peculiar genus, unnamed.

CONIFERÆ—

- Voltzia heterophylla*.
- Albertia*, sp.

If this flora be compared with that of the Damuda series quoted at page 134, a very marked difference will be noted, a difference nearly, if not quite, as marked as that which divides the Damudas from the Panchets, and which is considered by Dr. Feistmantel to justify the classification of the former as Bunter, and of the latter as Keuper. Out of four fairly recognized plants in the Panchet beds, one is a Damuda form, but it is the commonest and best preserved of the Panchet species. Of the sixteen species above mentioned only three are known to be found also in the Damudas, viz., *Glossopteris communis*, *Vertebraria Indica* and

Noeggerathia Hislopi; of these, *Vertebraria* is very rare and the *Noeggerathia* differs from the Damuda form, whilst the commonest plants of the Karharbári strata, *Gangamopteris cyclopteroides* and *Neuropteris valida*, are unknown in the Damuda series. Moreover, although the Talchirs are, as a rule, unfossiliferous, a few remains of plants have occasionally been found in them, and all hitherto found have been Karharbári species. It appears, therefore, clear that on palaeontological grounds the Karharbári beds must be separated from the Damudas and classed with the Talchirs, and that this distinction is confirmed by differences in mineral character between the Damuda and Karharbári beds. Thus, the lower Gondwáns of Bengal consist of three well-defined sub-divisions, Panchet, Damuda and Talchir, each with a distinct flora. I should add that Mr. Hughes, who has more experience of the Gondwána beds, and especially of the lower Gondwáns, than any other officer of the Geological Survey of India, concurs in the distinction of the Karharbári beds from the Damudas.

There can, at the same time, be no question that there is a distinct and very marked connexion between the flora just cited, and that found in the Bunter group of Europe. The connexion is, on the whole, not so great as that which exists between the plants of the Damuda series and those of the Australian coal measures; but still, if *Voltzia heterophylla* be correctly determined, and I see no reason for doubting the identification, one characteristic Bunter plant is present in the Karharbári beds, and two other Karharbári forms, *Neuropteris valida* and the *Albertia*, appear to be closely allied to the Bunter species. The connexion with the coal measures of Australia (Newcastle and Stony Creek) beds is not, on the whole, so strong as in the Damudas, although *Gangamopteris angustifolia*¹ is a species found in the Newcastle group, and the *Vertebraria*, *Glossopteris* and *Noeggerathia* are closely allied to Australian coal measure forms, so that altogether there is quite as good reason on the evidence of the flora for connecting the Karharbári beds by homotaxis with the Australian beds, classed as palæozoic by the most competent Australian geologists, as with the lower trias of Europe. In the Karharbári beds, too, as in all other Gondwána plant-bearing beds, there are relations to several different European formations. Thus *Equisetum Meriani* to which a Karharbári plant is said to be nearly allied is upper triassic (Keuper), *Sagenopteris* is upper triassic, rhætic and jurassic, being apparently best developed in the oolites; *Glossozamites* is not known below the lias.

It is urged by Dr. Feistmantel² that the triassic and mesozoic affinities of the Karharbári plants, belonging to the lowest known flora of the Gondwána system, tend to show that the Karharbári beds are "triassic or at least mesozoic," and he points out the bearing of this fact upon the age of the overlying Damudas. So

¹ This circumstance was not noticed by Dr. Feistmantel, Rec. G. S. I., Vol. IX, p. 138, when he recorded the occurrence of *G. angustifolia* at Karharbári. He only mentioned the existence of the species in Victoria "in certainly mesozoic rocks," together "with *Tæniopteris Daintreei*, McCoy, which is characteristic of mesozoic rocks in Queensland." See *ante*, p. 142. *Gangamopteris angustifolia* was originally described as a *Cyclopteris* by McCoy from the Newcastle coal measures, Ann. Mag. Nat. Hist. 1847, Ser. 1, XX, p. 148.

² Rec. G. S. I., Vol. X, p. 139.

far as it goes, the argument is fair and fairly urged, but it is not conclusive, and it cuts both ways. Dr. Feistmantel has omitted to note that there is nearly, if not quite as strong a link between the Karharbári beds and the upper coal measures of Australia, and he also forgets that if, as Mr. Clarke and other Australian geologists consider, those upper coal measures are palæozoic, and if fossil plants, like *Voltzia*, are adequate to determine age, the marked palæontological connection between the Damuda and Newcastle beds, more marked than the Bunter affinities of the Karharbári strata, would show the Damudas to be palæozoic, and the Karharbári beds are older than the Damudas.

TALCHIR GROUP.—The close association of the Talchir and Karharbári groups renders it probable that any age which must be assigned to the one must be attributed to the other also. The view appears to be gaining ground rapidly that the connection between permian and trias is greater than was at one time supposed, but there are numerous indications that the permian rocks, containing the poorest of all known faunas of a great geological epoch, and corresponding to the greatest change in animal and vegetable life of which any record has been preserved in the whole palæontological sequence, may have been, as suggested by Professor Ramsay¹ many years ago, a cold period like the Glacial epoch, which has in comparatively recent times affected our planet, but more severe or more prolonged. The evidence of ice-borne boulders in the Talchir beds, as pointed out by my brother, Mr. H. F. Blanford,² agrees with similar indications of glacial transport in England and in South Africa, and this clue, however faint, appears to me more promising than the relations of fossil plants.

It would, however, be an omission if I did not call attention to a fact which is of some importance, *viz.*, that in certain permian European floras mesozoic forms are much better represented than palæozoic. Compare, for instance, the list of plants recently described by Heer from Fünfkirchen.³ This flora comprises the genera *Baiera*, *Voltzia* and *Schizolepis*, all mesozoic types, together with *Ullmania*, which is peculiar to permian beds, there being but one carboniferous genus present.

In formulating the conclusions for which I have endeavoured to show my reasons in the preceding pages, I shall only notice the more important. If Dr. Feistmantel chooses to reply, I beg to point out that these are the essential questions to be decided. It is no answer to me to prove that I have overlooked some paragraph of his, or that I have made a slip about the name or relations of a fossil-plant. I do not pretend to a knowledge of palæo-botany, and I shall probably be shown to have erred in some trifling and secondary matters, as I did before. As no competent critic has hitherto attempted to analyse Dr. Feistmantel's work, and as I believe I have shown that work to be deficient in accuracy, I ask geologists to suspend their judgment as to his conclusions until these have been

¹ Q. J. G. S., Vol. XI, 1855, p. 198, &c.

² Q. J. G. S., 1875, p. 528.

³ Jahr. K. Ung. Geol. Anst., Vol. V, 1876, quoted in Verh. K. K. Geol. Reichsanst. Wien. 1877, p. 42.

re-examined by a practised palæontologist. My object is gained if I have called attention to the subject, and have defended my old colleagues from Dr. Feistmantel's systematic, if unintentional, tendency to disparage their work.

The conclusions are as follows:—

I. The evidence adduced by Dr. Feistmantel to prove that the Umia beds of Cutch are not upper jurassic would be insufficient, even if it were correct, and the greater portion of it is incorrect. Some of the forms, and amongst these the most important, quoted as evidence of an older age, really confirm Dr. Waagen's view that the beds are highest jurassic, (Tithonian or Portlandian) and the Cutch plant-beds may have been contemporaneous with Wealden, as Dr. Stoliczka considered.

II. The evidence brought forward to prove the Rájmahál beds lias is insufficient to justify the conclusion.

III. No sufficient proof of connection between the Panchet group and the Keuper has been adduced to show that the two are of the same age or related by homotaxis.

IV. The evidence on which the Mángli beds are classed as rhætic and as newer than the Panchets is based upon various mistakes and omissions, whilst the geological evidence upon which the Mángli beds were referred to the Kámthi group (probably older than Panchet) is indisputable, and would suffice to show Dr. Feistmantel's classification of the beds to be erroneous, even if his palæontological data were correct, which they are not.

V. In short, if the affinities of the plant-fossils with those in European rocks were alone regarded, the whole Gondwána system above the Karharbári group would be probably classed as equal to European beds from middle jurassic to rhætic, and it is highly probable that the lower Gondwána Damuda flora would be classed as newer than the upper Gondwána Rájmahál, as indeed it has been, in part at least, by no less authorities than De Zigno and Schimper. On the evidence produced by Dr. Feistmantel himself, both Rájmaháls and Panchets are most closely affined by homotaxis to the same minor European formation, the rhætic, although between the two Indian groups there is the greatest break, both stratigraphical and palæontological, in the whole Gondwána system.

VI. No evidence of any value has been produced to establish the classification of the Damuda series as lower triassic (Bunter); the Damuda flora has far less in common with the Bunter, or with any triassic European flora, than with that of the upper coal measures of Newcastle, &c., in New South Wales, and the mesozoic relations of the Damuda flora, which, after all, are not stronger than the affinities to the Australian upper coal-measure flora, are made out by selecting for comparison plants from various European formations ranging from middle jurassic to lower triassic.

VII. The classification given by Dr. Feistmantel, and stated to be on the authority of Mr Clarke, for the Australian plant-bearing beds, differs materially from all the data published by Mr. Clarke himself, and the union of the Newcastle beds with the Wyanamatta and Hawkesbury rocks instead of with the lower coal measures of Stony Creek, &c., is opposed to all the published evidence, and is

supported by arguments which are either inaccurate or insufficient. No reasons of any value have as yet been assigned for the separation of the Newcastle beds of Australia from the lower coal measures with marine fossils.

VIII. The Karharbári beds must be separated from the Damudas and classed with the Talchirs, and the palæontological distinction from the Damudas is equal to that on the strength of which the Panchets were removed from the Damuda series.

IX. It is just as reasonable to assert that the Damudas and Karharbári beds are carboniferous, because plants, such as *Glossopteris Browniana*, which are proved to be of carboniferous age in Australia, occur in the higher of the Indian groups, as it is to conclude that the whole of the lower Gondwánas are mesozoic because some triassic European forms, such as *Voltzia heterophylla*, are found in the inferior Indian subdivision, but in neither case is the evidence such as to render it wise to come to any positive and unqualified conclusion.

X. That the upper Gondwána may be taken approximately as equivalents of the European jurassic series, and the lower Gondwánas also approximately as triasso-permian, but that anything like close definition of minor horizons in the Gondwána system, or any attempt at establishing the exact correspondence of different groups in India and Europe is premature.

XI. Finally that, as the veteran botanist Alphonse de Condolle has recently pointed out,¹ an attempt to determine geological epochs in countries remote from Europe by fossil plants alone, can only lead to error. I doubt whether terrestrial and fresh-water animals are much more distinctive of geological age than plants.

On a review of the whole subject of the age of the Gondwána system I can only conclude, *first*, that Dr. Feistmantel's attempt to make all the Indian groups fit into the established grooves in the European sequence is a failure; and, *secondly*, that the constant assertion that particular groups belong to distinct European sub-divisions such as lias, Keuper or Bunter, is misleading and unscientific. I believe that the plan pursued by Dr. Oldham and by all the other members of the Indian Geological Survey before Dr. Feistmantel's arrival, of abstaining from any attempt at exact correlation, and of using due caution in suggesting relations of beds, was wiser and more scientific than Dr. Feistmantel's positive assertions as to the age of various Indian rocks.

ON "REMARKS, &C., BY MR. THEOBALD UPON ERRATICS IN THE PUNJAB."

(Records, Geological Survey of India, Vol. X, p. 223.)

Referring to these remarks, I wish to suggest that the ambiguity noticed disappears when the subject is considered from the general point of view in which it presented itself to me.

The erratics of the Punjab were treated of in my paper simply as wandering fragments, some of which could be attributed to ice flotation, and some to other

¹ Bibliothèque Universelle, Arch. Sci. Phys. Nat. 1875, Vol. LIV, p. 399.

local transporting agency ; though there was evidence to connect these also with glacial conditions.

I did not refer these erratics collectively to any particular or post-tertiary glacial period, because some of them presented indications of older glacial conditions. My object was to record the presence of travelled (erratic) masses, and the probable mode of accounting for them, rather than to establish their chronological relations, or advance theories regarding glacial conditions in the Punjab.

I think the origin most lately relied upon for the red granite blocks in the direction of the Salt Range open to uncertainty, both on account of the quantities of these blocks locally present, and of the disintegrating nature of granites generally, but still more, because the conformity of the whole Salt Range series, long since pointed out by Mr. Theobald (Journal, Asiatic Society of Bengal, XXIII, 1854, p. 656) is opposed to the idea that boulders derived from this series below the nummulitic groups could be enclosed in upper members of the same conformable sequence of beds.

The largest of these red granite blocks present no essential difference in their manner of occurrence from that of the other masses supposed to have been ice-borne ; they cannot be traced to local disintegration of a boulder bed below the *Obolus* zone, as this conglomerate does not occur in their vicinity, and they greatly exceed in size the blocks of the adjacent cretaceous (?) boulder bed.

Being evidently transported detrital masses, I conceive that the name "erratics" is applicable to the whole of these travelled boulders of the Upper Punjab.¹

A. B. WYNNE.

January 1878.

¹ Having so defined the word *erratic*, Mr Wynne is, of course, entitled to the benefit of the explanation. According to current usage, an erratic would certainly be understood to imply transport by ice, if not even an appropriation to the familiar glacial period. The essential meaning the word seems fitted to convey is some form of flotation distinct from the ordinary agencies of denudation. As meaning simply a stone not in place, the word would be of very little use.—H. B. M.

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[May.

ON THE GEOLOGY OF SIND, (SECOND NOTICE,) *by* W. T. BLANFORD, A. R. S. M.,
F. R. S., *Geological Survey of India.*

Introduction.—A brief account of the Geology of Sind, so far as the structure of the country had been ascertained by one short season's work, was given in the Records of the Geological Survey for 1876.¹ Two whole seasons, 1875-76 and 1876-77, have since been devoted by Mr. Fedden, and one season and part of a second by myself to the geological examination of the province, and, as might have been expected, several additions of more or less importance have been made to our previous knowledge, whilst in a few cases it has been found that our first conclusions were incorrect. As before, Mr. Fedden's notes are combined with my own, and I am indebted to my colleague for a large proportion of the observations made. Mr. Fedden has also added much to our knowledge of the fossil fauna by his collection and examination of the fossils, but the details must be deferred for the present.

The sub-division of the tertiary series in Sind into Manchhar, Gáj, Nari, Khirthar and Ranikot groups holds good, although the boundaries between the various sub-divisions have proved, in parts of the province, to be less distinct than in the Khirthar range, and there is the same remarkable appearance, that all the different tertiary formations are only of local value, and that all tend to pass into each other at a comparatively short distance from each typical section, which has been already noticed by Mr. Medlicott in the corresponding formations of the Punjab.² Some slight modification in the geological horizon

¹ Vol. IX, pp. 8-22.

² Rec. G. S. I., IX, pp. 50, etc.

attributed to the lower Manchhar beds has also been rendered probable, but in general there appears every reason for accepting the views put forward in the former paper as to the correlation of the different tertiary groups in Sind. It has, however, been found that, in the original classification, rocks were included in the Ranikot group, which belong in fact to a much lower horizon, and three small groups have been established beneath the lower tertiary subdivision and referred to the cretaceous epoch.

Errors in previous paper.—Before proceeding to notice the additions since made to the Geology of Sind, it will perhaps be best to call attention to a few statements in the previous paper which further examination of the country has proved to be untenable. The corrected general section will be found below, but there are a few details requiring alteration, besides the entire re-arrangement of the beds included in the first notice in the Ranikot group.

The supposed unconformity between the Gáj beds and the Nari group at Tandra Ráhim Khán, west of Sehván,¹ appears doubtful. Further examination of the junction between the two groups has failed to show any clear evidence of unconformable overlap.

The basaltic lava flow² is now shown to be at the base of the Ranikot group, and not intercalated, the beds below the volcanic rock being of different age.

Another error is in the statement³ that the Khirthar rocks compose several ridges near the Habb river, the southernmost of which terminates at Cape Monze. It is true that some ridges near the Habb consist of Khirthar rocks, and that the ridge west of the river, not far from the mouth, is composed of that formation, but the range terminating at Cape Monze proves on re-examination to be of Gáj beds resting on Nari. The mistake was due to the rocks having been first examined before the different sub-divisions of the Sind territories had been made out.

General section of rocks in Sind.—The following is the general section of the Sind rocks as corrected, the thickness of each group being estimated, as usual, where the beds are best developed. Very nearly, if not quite the full dimensions given, from the base of the lower Khirthar to the top of the Manchhars, are, however, exposed on the Gáj river, where, below the beds classed as lower Khirthars, nearly 4,000 feet of shales and limestones are seen, which probably belong to cretaceous formations:—⁴

¹ Rec. G. S. I., p. 16.

² *l. c.*, p. 22.

³ *l. c.*, p. 13.

⁴ In some brief notes published in the Proceedings of the Asiatic Society of Bengal for January 1878, pp. 4, 6, all these beds were classed as lower Khirthars, and the thickness of the group estimated at 10,000 feet, but subsequent study of Dr. Cook's descriptions of the Kelat rocks has shown that the unfossiliferous lower beds in the Gáj section may, like some very similar rocks south of Kelat, be really cretaceous.

Name.	Sub-divisions.	Approximate thickness.	Supposed geological age.	REMARKS.
1. Alluvial, &c. ...	.....	Unknown ...	Recent and post-tertiary.	
2. Manchhar ...	{ Upper ... Lower ...	5,000 ... 3,000 to 5,000	Pliocene ... Lower pliocene or upper miocene.	Apparently representative of the Siwaliks proper.
3. Gáj ...		1,000 to 1,500	Miocene.	
4. Nari ...	{ Upper ... Lower ...	4,000 to 6,000 100 to 1,500	Lower miocene? Upper eocene.	
5. Khirthar ...	{ Upper ... Lower ...	500 to 3,000 6,000 ?	Eocene ... Ditto.	Nummulitic limestone.
6. Ranikot ...		2,000 ...	Lower eocene.	
7. Trap ...	.....	40 to 90 ...	Upper cretaceous...	Representative of Deccan and Malwa trap.
8. Cretaceous ...	{ <i>Cardita Beaumonti</i> beds Sandstones.. Hippuritic limestone ...	350 to 450 700 320	{ Cretaceous ...	A bed of trap interstratified with the sandstone. Base of lower group not exposed.

Cretaceous beds.—The only part of Sind in which rocks of pre-tertiary age are known to exist is in the range of hills running south from Sehván. Various portions of this range are known by local terms, such as Dharan, Tiýún, Eri, Surjána, &c., but amongst the people of the country there is no name for the range as a whole. By Europeans the northern portion is sometimes called the Laki range, from the town of Laki, near the northern extremity, and for want of a better name this may be accepted. The old fortress of Ranikot is in this range.

The Ranikot beds themselves, it may be mentioned, as was already pointed out in the previous paper, extend over a considerable area to the east of the Laki range, and southward as far as Tatta. They are, however, not exposed anywhere in Upper Sind. The area of the beds beneath the Ranikot group extends northwards from the fortress of Ranikot to within four or five miles of Laki, a distance of about 22 miles. The outcrop, however, is not quite continuous, for the trap and underlying beds are covered up in places by the Ranikot group. The Hippuritic limestone, the lowest rock known to occur, is only exposed in a single locality. The range is very difficult of access, and there is a permanent supply of sweet water at only one spot, the fortress of Ranikot.

The spot where the Hippuritic limestone is exposed is at a place called Barrab, about 15 miles north of Ranikot. The range here consists of three parallel ridges. The eastern of these faces the plain sloping to the Indus, and consists of vertical or nearly vertical Khirthar limestone, on which, to the eastward, Manchhar beds rest unconformably. To the westward, Ranikot beds come in below

the Khirthar limestone, but have a reversed dip to the westward; then there is a fault with a considerable upthrow to the west, and, west of this, the cretaceous beds come in with a low western dip. They are exposed in a high scarp and form the second or intermediate ridge. From this point there is a gradually ascending section to the westward, the soft upper cretaceous and Ranikot beds cropping out in the valley between the intermediate ridge and the western or main range, which is formed of Khirthar or nummulitic limestone.

The lowest beds seen are a hard compact white limestone, white or grey in colour, pure below, but becoming gritty above. No nummulites occur: fossils abound, but are only seen in section, and they weather out so badly that only one fairly recognizable specimen has been obtained. This specimen, however, is of importance, as it appears to be a portion of a Hippurite, one of the most characteristic of cretaceous fossils.

The peculiar interest attaching to the discovery of this fossil, if the identification be correct, is due to the circumstance that the principal cretaceous formation in Persia is a limestone containing Hippurites, and that this limestone has been found extending over a large tract of country from Lake Urumiah in north-western Persia to south-east of Karmán. This last locality, however, is about 700 miles from the spot where cretaceous rocks are found in Sind, and the Hippuritic limestone has not hitherto been recognized in Baluchistan, where, however, cretaceous rocks are certainly present. The bed in Sind differs much from the characteristic form of the Persian rock, but the latter is of great thickness; some 8,000 feet at least, in the neighbourhood of Karmán, apparently belonging to the formation, and it includes many beds varying in mineral character.

The gritty limestones on the top of the white Hippuritic limestone pass upwards into a group of dark-coloured sandstones of considerable thickness, and forming the intermediate ridge of hills already mentioned. The dark colour of the beds makes these hills conspicuous from a distance, and enables them to be distinguished at once from the two whitish limestone ranges to the east and west. The sandstones are usually coarse, sometimes conglomeratic and often calcareous, the prevalent colour is dark-brown or purple, and many beds are highly ferruginous, a few bands of dark-red shale, containing much iron, being interstratified. On the top of the sandstones is a thick bed of dark-coloured impure limestone containing oyster shells and some other fossils, amongst which are some large bones, apparently of reptiles, but all hitherto found were too imperfect for identification.

In one place a bed of basalt about 40 feet thick was observed by Mr. Fedden interstratified in the sandstones, and it is probable that this band may exist elsewhere, although it has been overlooked. The position of this bed of trap is about 300 or 400 feet above the top of the Hippuritic limestone, and about twice that distance below the main band of basalt at the base of the Ranikot group.

The highest sub-division of the cretaceous rocks consists of olive shales and sandstones, for the most part soft and fine-grained, but occasionally hard and calcareous. The beds of sandstone have very frequently an "ashy" appearance, as if they contained decomposed grains of basalt or some similar volcanic rock, or fine volcanic lapilli, or they may be an admixture of the products of submarine volcanic outbursts with ordinary sediments. Gypsum is of common occurrence

in the shales. These olive shales and sandstones are highly fossiliferous, the most common and conspicuous fossils being *Cardita beaumonti*, the affinities of which are shewn by D'Archiac and Haime to be with a cretaceous form, and a *Nautilus*, which Mr. Fedden has, I believe correctly, identified with *N. bouchardianus*, a Gault species in Europe, but found in the upper cretaceous beds (Ariálúr) of Southern India. Another species of *Nautilus* also is allied to some cretaceous types. The first named species may be *N. labechei* of D'Archiac and Haime, from which it only differs in the siphuncle being median instead of interior, but this character sometimes varies with age in *Nautili*. Amongst the other fossils occurring is a species of *Epiaster*, a genus of Echinoderms almost confined to upper cretaceous beds. The only form in the olive shales hitherto identified as common to the Ranikot group is *Corbula harpa*. Besides the above, species of *Cidaris* and of an Echinoderm allied to *Pygorrhynchus*, *Rostellaria*, *Cypræa*, *Natica*, *Turritella*, *Cardium* and *Ostrea* occur, with two species of Corals. A few imperfect Reptilian vertebræ have been determined by Mr. Lydekker as belonging to an Amphicælian Crocodilian with distinctly mesozoic affinities.

All the cretaceous beds abovementioned appear to be perfectly conformable to each other and to the overlying trap. It is premature to attempt correlation of these cretaceous rocks, but it may be remarked, that some peculiar olive shales, which underlie the nummulitic limestone of the Salt Range in the Punjab conformably, and which have been classed by Dr. Waagen as probably of cretaceous age, may represent the very similar beds in Sind.

Deccan trap.—Besides the bed of trap just noticed as occurring interstratified with the cretaceous sandstones, the basalt first observed at Ranikot in 1863,¹ and subsequently found further north at Jakhmari and other places,² has now been traced throughout the whole distance, upwards of 20 miles, between Jakhmari and Ranikot, wherever the base of the Ranikot beds is exposed. The thickness of the trap varies from about 40 to about 90 feet, the average being 60 or 70. The only rock is basalt, of which, in places, there appear to be two flows similar in mineral character; the upper portion of each flow is amygdaloidal.

In the previous paper on Sind Geology, it was stated³ that the relations of the trap were obscure, and although this was corrected in a postscript⁴ so far, that the interstratification of the trap flow was said to have been clearly ascertained, the most important point, the probable relation of the volcanic rock in question to the great Deccan and Malwa trap series, was left undetermined. The interest of this question and the possibility that the basalt seen for a few feet only in the bed of the stream at Ranikot might be a representative of the Deccan trap, were naturally mentioned in the first notice of the occurrence.⁵ The trap series, it may be remembered, has been traced from the Deccan and Malwa throughout Kattywar and Cutch, to within about 150 miles of Ranikot, so that

¹ Mem. G. S. I., VI, p. 5.

² Rec. G. S. I., IX, pp. 11, 22.

³ *Ib.*, p. 11.

⁴ *Ib.*, p. 22.

⁵ Mem. G. S. I., VI, p. 12.

the representation of this great volcanic formation in Sind is far from improbable. The question as to whether the Ranikot trap belongs to the Deccan series may now be answered in the affirmative. There is conclusive evidence that this rock is interstratified and not intrusive, for it occupies precisely the same position above the highest *Cardita beaumonti* beds, and below the base of the Ranikot group, for over 20 miles, and appears to be conformable with both, whilst not a single vertical dyke has been noticed in the country. The mineral character of the basalt is precisely that of a very common form of the Deccan trap, whilst two mineral peculiarities—the occurrence of amygdala, surrounded by green earth, and of cavities containing quartz crystals, with trihedral terminations—are both characteristic of the trap rocks of Western India. The geological position also at the base of the tertiary series corresponds with that of the trap series in Cutch and Guzerat.

It is clear, however, that the thin flows of basalt in Sind can only represent a portion of the great Deccan trap period, and the lower band in the cretaceous sandstones indicates that all the upper cretaceous beds between the two trap flows were, in all probability, contemporaneous in origin with the Deccan trap series. If now the age of the *Cardita beaumonti* beds has been rightly determined as upper cretaceous, the identification of the Sind representative beds confirms the views previously held by myself, but by no means generally accepted by my colleagues,¹ as to the cretaceous age of the lower portion, at all events, of the Deccan trap series.

Ranikot group.—It was mentioned in a postscript to the previous paper in the Records² that the highly fossiliferous brown limestones seen north-west of Kotri and near Jhirak (Jhirk or Jerruck) and Tatta must be classed with the Ranikot group, and not with the Khirthar. A list of fossils obtained from these brown limestones was given,³ but from this list two species must be removed, viz., *Cardita beaumonti* and *Nautilus labechei*, the species thus identified (the identification is doubtful in the case of the *Nautilus*) being from the olive shales now classed as cretaceous. It was also noticed in the postscript that south of Ranikot there is distinct unconformity between the Khirthar limestone and the Ranikot group, the upper members of the latter being deficient in the Laki range, and there being at one place evidence of the lower group having been slightly disturbed and denuded before the deposition of the Khirthar limestone. The break between these two formations is, however, probably not indicative of any great interval in time, for several of the Ranikot fossils pass upwards into

¹ Oldham: Rec. G. S. I., IV, p. 77; Wynne: Mem. G. S. I., IX, p. 48. I have lately had occasion to go over all the evidence again when writing a chapter on the Deccan traps for the Manual of Indian Geology, and it appears to me that the arguments in favour of considering the traps tertiary are weaker than I at first supposed. Only one fact of any importance, so far as I know, has ever been adduced: the supposed identification of certain freshwater shells in the intertrappean beds of the Deccan with forms found in the lower eocene plastic clay of Belgium. Apart from the question, a very important one, whether freshwater shells afford trustworthy evidence of age, I greatly doubt the validity of the identification.

² Vol. IX, p. 21.

³ *l. c.*, p. 14.

the Khirthar beds. In some cases, it is true, there does appear to be a change of species: thus *Eurhodia morrisi*, a common Ranikot echinoderm, appears to be represented by *E. calderi* in the Khirthar beds, but still there is much evidence of transition, for the lowest Khirthars near Jhirk and Tatta have much the character of the Ranikot limestones, and there is a gradual passage from the one to the other; so much so indeed, that Mr. Fedden has found it difficult to the southward to determine any exact limit between the two, and to map their boundaries.

All the lower portion of the Ranikot group consists of soft sandstones and shales, much variegated in colour. The only fossils found are land plants; many of the shales are pyritous, and gypsum is of frequent occurrence. It appears highly probable that these beds are of fluviatile origin, and their occurrence immediately above the trap may indicate that the latter was of subaërial formation in Sind, as elsewhere.

CRETACEOUS AND LOWER TERTIARY BEDS OF BALUCHISTAN.

In 1875, from the top of the Khirthar range in upper Sind, lower beds were seen cropping out west of the British frontier from beneath the Khirthar limestone. At that time, owing to political complications, there was a difficulty in visiting any part of Baluchistan; but in 1876-77, this difficulty having been removed, I was enabled to examine the sections on the upper Gáj, the only river which actually cuts through the Khirthar range. The beds beneath the Khirthar limestone at this spot proved to be utterly different from those seen in the same relative position in the Laki range. The following is a rough section of the beds on the upper Gáj, with their approximate thickness by estimate:—

KHIRTHAR	...	{	1. Massive nummulitic limestone forming the crest of the Khirthar range	1,200
			2. Shales, marls, and clays, mostly dark olive in colour and abounding in <i>Nummulites</i>	500
			3. Hard grey limestone with <i>Nummulites</i>	60
			4. Argillaceous limestone, shales, and clays, olive and bluish grey in colour, abounding in <i>Nummulites</i>	400
LOWER KHIR- THAR.		{	5. Unfossiliferous olive and bluish grey clays and nodular shales; no limestone bands	1,500
			6. Pale-brown sandstones in thick beds, with traces of vegetables ...	1,000
			7. Fine greenish white sandstone and shale, some of which is carbonaceous	500
			8. Dark-brown limestone and dark-green argillaceous beds, with <i>Nummulites</i>	100
			9. Pale-grey argillaceous limestone, with but few fossils. One band towards the base contains <i>Nummulites</i> and <i>Alveolina</i> ...	200
			10. Fine dark-coloured shales, unfossiliferous	3,000
? CRETACEOUS		{	11. Very fine grained homogeneous thin-bedded limestone, white, red, grey or ochrey in colour, unfossiliferous, forming a conspicuous range of hills	1,200
			12. Hard grey shales, with calcareous bands, from an inch or two to a foot in thickness	2,500
				<hr/> 12,160 <hr/>

Not a single bed below the Khirthar limestone (No. 1) can be recognized as identical with any of the formations in the Laki range, although the distance between the two localities is only about 90 miles. In the upper Gáj section, there are no fossiliferous brown limestones, no trap, no olive shales with *Cardita beaumonti*, no dark ferruginous sandstones nor hippuritic limestone. The sandstones Nos. 6 and 7 may represent the lower Ranikot beds, but the resemblance is not great, and there is no palæontological connexion between the two.

The examination of the section was hurried, and it is far from improbable that some fossiliferous bands may have been overlooked, but no distinct break in the sequence was detected; perhaps for want of palæontological evidence. The division between upper and lower Khirthar, and between the latter and the supposed cretaceous beds, is arbitrary; the limestones No. 8 contain the same species of *Nummulites* as Nos. 2, 3, and 4, and no fossils were found below No. 9. The sole reason for distinguishing the 6,000 feet of beds, from No. 5 to No. 10 inclusive, as lower Khirthars, is that, as the nummulitic limestone No. 1 is the same bed at the Gáj as in the Laki range, some of these lower beds must represent the Ranikot group. At first it was supposed that all the lower beds on the upper Gáj section were tertiary, and the lower Khirthar beds were estimated to have a thickness of 10,000 feet, but on subsequently reading more carefully Dr. Cook's account of the geology of Kelat,¹ and Dr. Carter's notes on Dr. Cook's discoveries,² it appeared to me that the peculiar fine-grained banded limestones No. 11 must be the same as some red and white limestones extensively developed at no great distance to the north-west. These red and white limestones pass down into some argillaceous beds (perhaps the same as No. 12 of the above section), in which Dr. Cook found *Ammonites*, and he consequently classed both rocks as mesozoic.

It is probable that the beds below the Khirthar limestone occupy a large tract in Baluchistan to the west of the Khirthar range, for similar beds are seen to the westward from the crest of the hills as far north as Darhyáro. Again, west of the Habb river, forming the western boundary of lower Sind, the whole Khirthar formation appears composed of shales, marls, and sandstones, closely resembling the lower Khirthar beds of the upper Gáj section, and an enormous mass of similar beds is found to the westward in Makrán.³ A peculiar banded red and white limestone, so closely resembling that on the upper Gáj that these two are probably identical, forms a small hill at Gadáni on the sea-coast, about 25 miles north-west of Karáchi.

Khirthar group.—The nummulitic limestone of the Khirthar and other ranges in Sind varies much in thickness, and the original estimate of 3,000 feet may have been excessive, though it is doubtful whether it is too high in the northern part of the Khirthar range, where the limestone must be very thick. At the Gáj, as we have seen, this bed does not exceed 1,000 or 1,200 feet in thick-

¹ Bom. Med. & Phys. Soc. Trans. November 1860. I am indebted to Dr. Cook for a copy of this interesting paper.

² Jour. Bom. Br. Roy. As. Soc., VI, p. 184.

³ Eastern Persia, II, pp. 460, 473.

ness, and farther south it diminishes still further. In the Laki range it is probably not more than 500 or 600 feet, and towards Jungshahi and Tatta it is perhaps even less. Here it rests upon Ranikot beds. But to the westward in the Habb valley the Khirthar limestone disappears entirely, and it appears to thin out within the space of a very few miles. The Khirthar range is composed of the limestone throughout, and terminates to the southward inside the province, near a police post called Karchát, about 50 miles south by a little west from Sehván. The southern extremity of the range, like several other ridges, is an anticlinal, so that the thickness of the limestone is not seen, but it must be considerable, and can scarcely be less than 500 or 600 feet. About 8 miles west of the Khirthar, the top of the ordinary limestone is seen underlying Nari beds, but in the next low ridge to the westward, only about 4 miles farther, the Khirthars are brought up by a fault, and the typical pale-coloured limestone is found to be completely wanting, and replaced by dark-coloured grey limestones containing *Echinodermata* and *Nummulites*, and interstratified with shales and sandstones precisely like those of the Nari group. A few miles farther west, in the Hamlig range, about 25 miles from the Khirthar, not a trace of the massive Khirthar limestone could be detected. The locality is beyond the Sind frontier, and the examination was so brief, that some fault may have been overlooked, but at this spot, and in some other localities further south, the Nari sandstones appeared to pass downwards gradually into shales and sandstones, with some beds of marl and dark-coloured argillaceous limestones, containing the typical Khirthar nummulites, *N. granulosa* and *N. obtusa*, &c. These beds precisely resemble some of the beds below the Khirthar limestone on the upper Gáj. The brown and yellow Nari limestones, too, are only faintly represented towards the base of the group by thin bands containing *Orbitoides papyraceus*.

Nari group.—No alteration is necessary in the general description of this group. Throughout the Khirthar range, the whole upper portion, 4,000 or 5,000 feet thick, consists of sandstones, with a few scattered beds of shale or conglomerate, and destitute of fossils, with the exception of a few vegetable markings, too imperfect for recognition. The lower sub-division of the group varies in thickness from 100 or 200 feet to as much as 1,500, and consists of shales and thin bands of sandstone, with brown and yellow limestones; the latter chiefly developed towards the base, and containing *Nummulites garansensis*, *N. sublævigata*, and *Orbitoides papyraceus* (or *fortisi*).

It has already been mentioned that in the Habb valley, in south-western Sind, there is a gradual passage from the upper Khirthar into the Nari beds, and there is in the same area an equally evident tendency to a passage between the Nari and Gáj groups. The Nari group in the Habb valley is probably as thick as in the Khirthar range; but although the prevailing rocks are still sandstones, brown limestones with *Orbitoides papyraceus* are found in the middle of the group, instead of being confined to the lower portion, whilst the typical limestone bands at the base of the group appear to be ill developed. Now, Mr. Fedden noticed some time since that bands of limestone, with apparently the same *Orbitoides*, are found in the Gáj group; and in the upper part of the Nari group bands of marine fossils occur, containing Gáj species, such as *Ostrea multicostata*

and *Pecten subcorneus*. The boundary between the two groups is consequently, to some extent, arbitrary.

On the other hand, Mr. Fedden has observed at one spot on the west side of the Laki range, a few miles from the northern extremity of the range near Sehván, distinct unconformity between the upper and lower Nari groups, the sandstones forming the higher portion of the group resting upon the denuded edges of the brown limestones composing the lower sub-division. This is an excellent example of the manner in which the sub-divisions of the tertiary series change, the groups of one locality passing into each other, and new breaks occurring. It should be remembered that the Nari beds are entirely wanting east of the Laki range, and Manchhars, with, in places, a thin representative of the Gáj beds at their base, rest unconformably on Khirthars.

Gáj group.—There is but little to add to the general description of this group also. A measured section of the beds on the Gáj river, where they are especially exposed, shows that the whole thickness of the group is but little less than 1,500 feet at that spot. To the northward the thickness of the Gáj beds must be less, and it is probably smaller in lower Sind also. On the Gáj the greater part of the whole thickness consists of sandy shales and clays, with gypsum, the hard limestone beds, though far more conspicuous, being only subordinate. In the Habb valley however, where the Gáj beds form extensive plateaus, surrounded by scarps in which the rocks of the group are well exposed, the mass of the Gáj strata appears to consist of limestone, and the boundary between them and the Nari, with which, as has just been noticed, bands containing Gáj fossils are interstratified, has been drawn at the base of the limestones. At one spot, a thickness of 500 feet, entirely composed of limestone, was measured (by aneroid) at the base of the group, and this thickness seems to include the greater portion of the Gáj strata in this locality.

It has already been mentioned that the supposed unconformity between the Gáj and Nari groups west of Sehván at Tandra Ráhim Khán proves, on further examination, to be doubtful. But the Gáj group in the country south of Sehván completely overlaps the Nari in places, and rests upon Khirthar beds. In this country, however, the Gáj itself is but poorly represented, and frequently is either entirely wanting, or appears as merely a thin band at the base of the Manchhar group.

The passage from Gáj to Manchhar, despite the unconformity shown by overlap, and the presence of Gáj pebbles in Manchhar beds, is locally just as complete as any of the other cases of transition already mentioned. In the paper published in 1876, the transition beds containing estuarine shells in the Khirthar range were mentioned. Some of the estuarine shells are by no means confined to this belt; *Corbula trigonalis*, for instance, occurs in beds near the base of the Gáj group, and has also been found in one band in Manchhar rocks, about 300 or 400 feet above the top of the Gáj. As will be shown presently, there is in the neighbourhood of Karáchi even stronger evidence of the close connection between Manchhar and Gáj beds.

Although the number of Gáj fossils have been somewhat increased, the additions have been less extensive than in the case of many of the other groups.

Amongst the most important additions are, *Vicarya verneuili*, found by Mr. Fedden in some of the upper beds of the Gáj section; a small crab, *Typilobus granulatus*, originally described by Dr. Stoliczka from Cutch,¹ and several of the corals described by Professor Martin Duncan in 1864. All tend to support the opinion that the Gáj beds are miocene, and rather upper than lower miocene.

Manchhar group.—The additions to our knowledge of this group are of more importance. Some of the most interesting have been already noticed in these "Records" and in the "Palæontologia Indica" in the shape of descriptions by Mr. Lydekker² of the mammalian remains obtained by Mr. Fedden and myself. During the last season that I was engaged in Sind, Hira Lal, one of the native assistants of the Survey, was attached to my camp, and he succeeded in finding a considerable number of specimens, chiefly small fragments, but including several teeth. Some Baluch shepherds also, living along the Laki range, were induced to collect, and altogether, although the bones and teeth are rare, and but few of those found are recognizable, sufficient material was collected to enable a considerable number of species to be identified by Mr. Lydekker. The comparison of these with the comparatively well known Siwalik fauna has shown a striking difference; most of the species being different, and the general facies of the Manchhar fauna being much older. This distinction is, I think, explained by the geology.

The possibility of a sub-division of the Manchhar group was noticed in 1876.³ Although it is very difficult to draw an absolute line of separation, there can now be no doubt that the Manchhars may be divided, somewhat roughly it is true, into an upper and a lower sub-group. The lower consists mainly of the characteristic grey sandstone, with occasional red sandstones, and, towards the base, brown or grey and red clays; the latter, however, are of small thickness compared with similar beds in the upper sub-group. Conglomeratic bands are common, and are frequently ossiferous, but they chiefly contain nodules of clay and soft sandstone, and no nummulitic limestone pebbles have been detected in them. It is from these beds that nearly all the mammalian fossils found in the Khirthar range have been derived.

The upper sub-group, where it is best seen in the northern portion of the Khirthar range, is thicker than the lower, and consists principally of beds of orange and brown clay, with subordinate bands of sandstone and conglomerate. The sandstones are usually light brown, but occasionally grey beds occur, like those characteristic of the lower sub-division. The highest part of the formation contains more sandstone and conglomerate, and the whole is capped by the massive conglomerate, which forms the ridge extending along the edge of the Indus alluvium. These conglomerates of the upper Manchhars differ from those of the lower by containing pebbles of nummulitic and Gáj limestone. Bones are rare, and only a few fragments, too imperfect for identification, have been found.

¹ Pal. Ind., Ser. VII, p. 15, Pl. III, figs. 3—5.

² Rec. G. S. I., IX, pp. 91, 93, 106; X, pp. 76, 83, 225; XI, pp. 65, 76, 77, 79, &c.; Pal. Ind., Ser. X, pt. 2.

³ Rec. G. S. I., IX, p. 17.

In lower Sind, whence a large proportion of the mammalian remains have been procured, this sub-division of the Manchhars has not been traced; the beds are poorly exposed, and it is by no means clear that in this ground, where the lowest Manchhars rest unconformably on the Khirthars, the two sub-divisions can be distinguished by the presence or absence of nummulitic limestone pebbles. Several of the fossil forms, however, are identical with those found in the lower Manchhars to the northward, and there can be no reasonable doubt that the fossiliferous beds are on the same horizon. That the Manchhar beds are probably much less developed in lower than in upper Sind is shown by the circumstance that the section of the group, which can scarcely comprise less than 8,000 to 9,000 feet of beds, west of Lárkána and Mehar, has diminished to about 3,000 feet at Tandra Ráhim Khán, west of Sehván. The principal localities for fossils are near the Gáj, where mammalian remains were first found by Vicary, and whence Mr. Fedden obtained several good specimens in 1876. Bones have also been found more recently on both sides of the Laki range, south of Sehván.

It has already been mentioned that an estuarine bed is found at one place some 300 or 400 feet above the base of the Manchhars. This is near the Nari Nai, north-west of Sehván. In lower Sind, and especially near Karáchi, marine or estuarine bands containing oysters and other shells become of frequent occurrence in the Manchhar beds, and some of these bands contain Gáj fossils; so that there is to the southward the same transition between Nari and Gáj which has already been shown to take place between all the other tertiary groups. It is clear that the lower Manchhars are of the same age as the Gáj beds, and if, as appears certain, the latter are Miocene, the lower Manchhars may be considered as upper Miocene.

This view is in accordance with the fauna, which includes only three living genera, *Rhinoceros*, *Sus*, and *Manis*; the generic identification in the last case is doubtful, being founded on a single phalange, and both the other forms existed in Miocene times. Besides these, *Amphicyon*, *Anthracotherium*, *Hypopotamus*, *Hyotherium*, some new genera related to *Merycopotamus*, and *Dinotherium*, are found in the Manchhar beds, but not in the Siwaliks, whilst the living types, *Semnopithecus*, *Macacus*, *Felis*, *Hyæna*, *Ursus*, *Cervus*, *Bos*, *Capra*, *Camelus*, *Camelopurdalis*, *Equus*, *Elephas*, &c., which abound in the Siwaliks, have not been found in the Manchhar beds, so that, although several species, such as *Rhinoceros palæindicus*, *Acerotherium perimense*, *Chalicotherium sivalense*, *Sus lysudricus*, and two species of *Mastodon*, are common to the two, the presence of the much larger number of extinct forms, most of which are typically miocene in Europe, and the paucity of living genera, stamps the Manchhar fauna as of earlier date than the Siwalik.

Now, the Manchhar fauna, as has just been shown, occurs in the lowest Manchhar beds, whilst the Siwalik species are from the upper portion of the group. It is therefore far from improbable that the upper Manchhars represent the Siwaliks. The lower Manchhars may represent the Náhans of the Sub-Himalayas, or some of the lower portions of the Siwaliks themselves. The great distinction between the Manchhar and Siwalik fauna supports Mr. Lydekker's opinion, that the latter is of Pliocene age.

Nothing more has unfortunately been determined as to the relations between the Manchhar and Makrán groups. The former has not been traced to the west of Cape Monze, near Karáchi; at least no such rock could be detected during a traverse of the coast as far as Sonmiáni made for the purpose of endeavouring to trace the connexion between the two formations. The Makrán group, on the other hand, appears not to extend much to the eastward of Hingláj, so that there is a break between the two of the whole breadth of Sonmiáni bay—60 or 70 miles at least. Some of the Manchhar beds near Karáchi closely resemble certain strata in the Makrán group, but the typical whitish marls of the latter have not been noticed in Sind.

General sequence of tertiary beds in Sind.—We have thus in Sind a great sequence of later mesozoic and tertiary rocks, in which, despite the evidence of great changes in the conditions under which they were deposited, and despite local unconformities, there is no proof of any general break in the sequence throughout the province. In some places, as in the Laki hills, where upper Miocene Manchhars rest unconformably upon middle Eocene Khirthars, there is no question that elevation, and in all probability denudation, took place in the interval between the two formations, but elsewhere, as to the westward in the Habb valley, and to the northward on the flanks of the Khirthar, the break which exists in the Laki hills is represented by an uninterrupted sequence of the Nari and Gáj groups. At the close of the tertiary period, however, there is a great break, and the latest Manchhar (Pliocene) conglomerates are as constantly turned on end along the edge of the Indus alluvium as the very similar Siwalik conglomerates are in the Punjab.

The lower portion of the Ranikot beds, the upper Naris, and the Manchhars must have been deposited near land, for they contain terrestrial organisms, and all are probably fluviatile deposits; whilst the upper Ranikot, Khirthar, lower Nari and Gáj beds are clearly marine. Of all the marine beds, the Khirthar nummulitic limestone is the most important, and it is, as a rule, remarkably free from admixture of sand or other indications of the neighbourhood of land, but, as has been shown, this limestone is intercalated with sandstones and shales in lower Sind, and it entirely disappears in the south-western part of the province near the Habb river. The Gáj beds, on the other hand, are interstratified with sandstones and shales in the northern part of the province, but have a much more distinctly marine aspect to the southward, where limestones prevail. It is premature to reason broadly as to the changes in the distribution of land and water during the tertiary period until the rocks of Baluchistan are better known; all that can be done now is to point out the leading facts connected with the evidence afforded by the rocks in Sind itself; but it is impossible to avoid calling attention to the much greater prevalence of marine conditions during later Eocene and Miocene times in Sind than in the Punjab area to the northward, where no marine beds of later date than the nummulitic limestone have hitherto been detected.

ON THE ORIGIN OF THE KUMAUN LAKES BY V. BALL, M.A., F.G.S.,
Geological Survey of India.

In so far as the outer and lower ranges of the Himalayas are concerned, the group or series of lakes described in the following pages is in several respects quite unique.

To many out of the thousands who have visited the beautiful part of the country where these lakes are situated, the question of their origin must have presented itself. Doubtless, it is in consequence of the difficulties which surround the subject, that no one has ventured to publish his observations and deductions in full.

To Mr. H. F. Blanford, I believe, belongs the credit of having first¹ suggested in print² an origin for them. But the subject has often been discussed, and three or four years ago it was specially commended to my notice by one who has frequently visited Naini Tal, and whose acquaintance with the Alps and the literature of the subject led him to suspect that that lake might possibly have been excavated by an ancient glacier.

Could I foresee within the next few years any prospect of my being able to carry on my examination of the ground, I should not have presented this unfinished sketch; but as I do not do so, I think the publication of the facts here given desirable, as it may facilitate the speedy final solution of the question, and may also have the advantage of eliciting the opinions of experienced glacialists, who are unable to visit the locality for themselves.

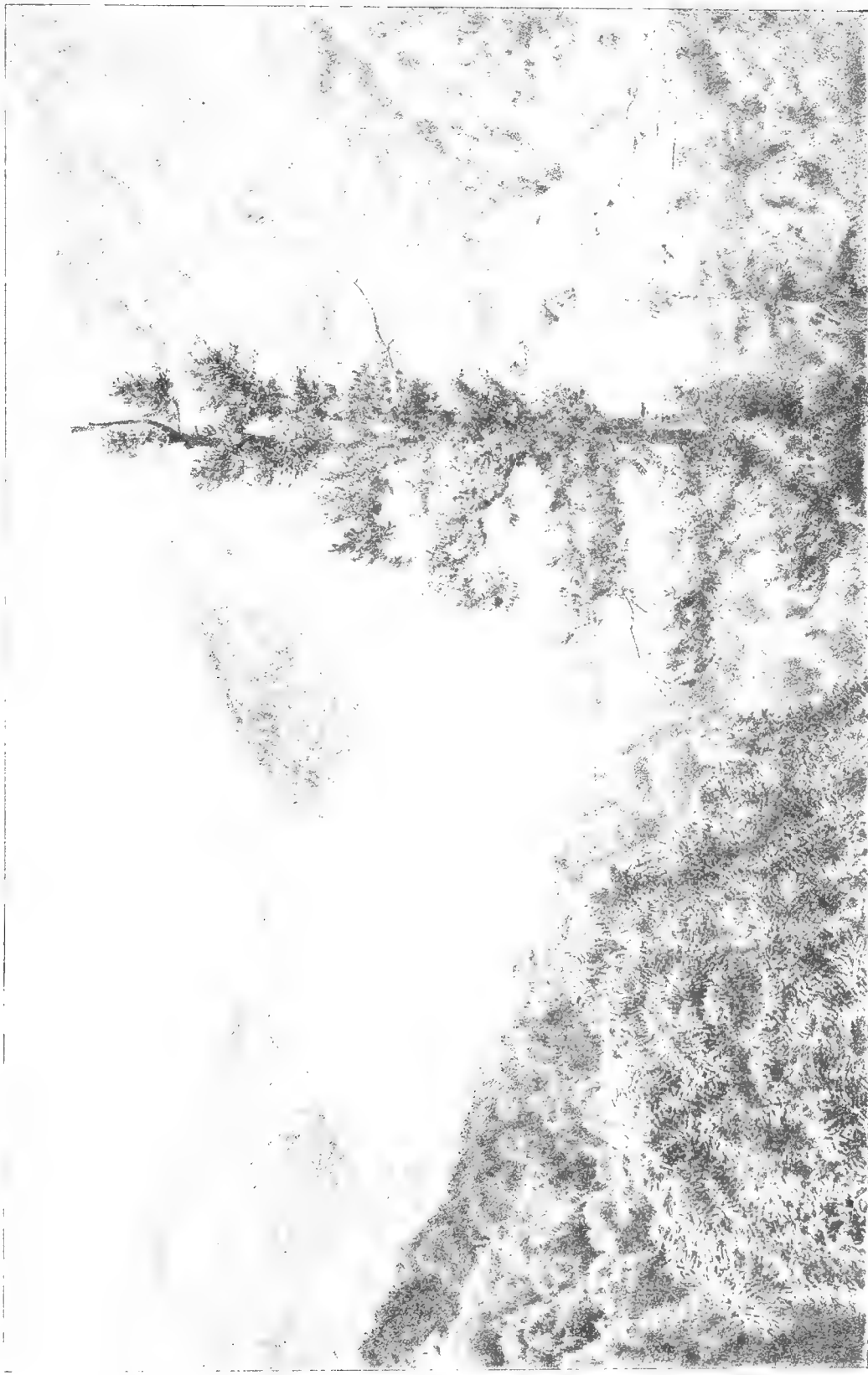
During a recent visit to Naini Tal, I had hoped to have been able to have prepared a detailed geological map of the neighbourhood of the lakes, but circumstances beyond my control arose, which diminished my time for exploration by two-thirds. Though the area is not extensive, the complex and disturbed nature of the beds renders their true appreciation and demarcation a by no means easy task. Owing to landslips, and the fact of so large a portion of the basin of Naini Tal being built over, the accurate mapping of individual beds and of the trap will require much time to accomplish.

Of the age of the unfossiliferous metamorphosed schists in which the lakes occur nothing is certainly known. In the account of the Geology of Kumaun and Garhwal by Mr. H. B. Medlicott³ will be found such information as exists on the subject. Some casual observations on the geology which bear upon the physical origin of the lakes will be found in their places below; otherwise there is no intention of giving a detailed account of the stratigraphy in this paper. Besides the map on the scale of one inch to a mile, shewing the relative positions of all the lakes, it has been considered advisable to give with this paper a copy of the large scale map of Naini Tal, which indicates very beautifully and with extreme fidelity the physical structure of the neighbourhood.

¹ Unless General Strachey's remark, that an outburst of amygdaloidal trap "is associated with the formation of several small lakes," is intended to be read as implying cause and effect.—Quar. Jour., Geol. Soc., Vol. VII, p. 298.

² Proc. As. Soc., Bengal, January 1877, p. 3.

³ *Vide* N.-W. Provinces Gazetteer, edited by E. Atkinson, Esq., C.S.



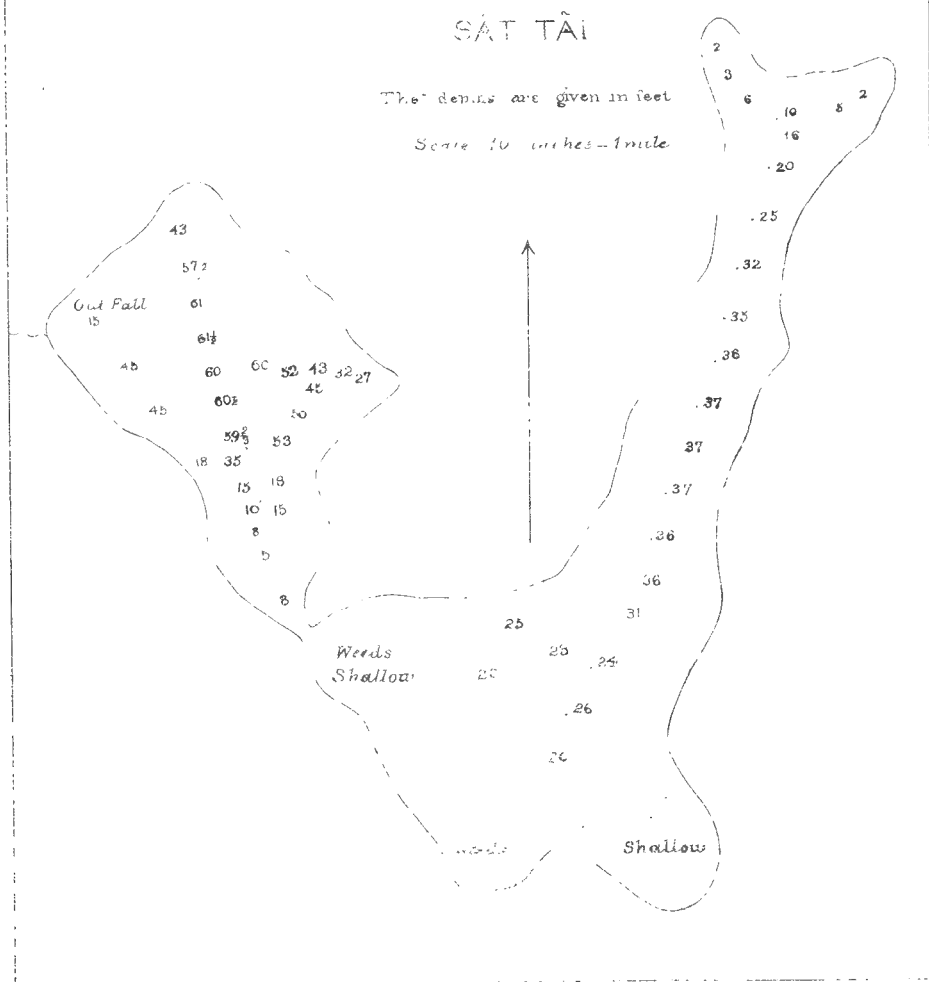
GENERAL VIEW OF NAINITAL.

(From a photograph by Sagar.)

SAT TAI

The depths are given in feet

Scale 10 inches = 1 mile



This series of *Tals* or lakes is included in the Chhakata pargana of Kumaun.¹ They are by no means all of equal size or importance. They seem, however, to fall naturally into three classes, the members of each class having certain features mutually in common. So arranged, they would stand as follows:—

- Class I.—Naini, Bhim, Malwa.
 „ II.—Naukachia, Sat.
 „ III.—Kurpa, Dhobie, Saria, Sukha, Khoorea, &c.

NAINI TAL.—This lake, so called after a Hindu goddess, is situated about 10 miles in from the southern slope of the hills. It lies at the bottom of a valley, which runs about north-west south-east, and is surrounded on all sides, except at the outfall on the south-east, by lofty ridges, which serve to give an unusual amount of definition to the limits of the catchment area.

The greatest length of the lake itself is 4,703 feet, the maximum breadth 1,518 feet,² and the elevation of the surface at high water about 6,409 feet above the sea. The principal peaks on the encircling ridges are Luria Kanta, 8,144 feet; Sher-ki-danda; Ulma; China, 8,568³; Deopathar, 7,989; Iarpathar, 7,721.

The China (Cheena) portion of the ridge at the head or north-west end of the valley is steeply scarped above, with an undercliff much concealed by talus brought down by landslips. It consists chiefly of shales, with which there are some quartzites, and, towards the crest, there are limestones, which, so far as is clearly seen, may partake either of the nature of beds or veins. Passing hence round by north to south-east the ridge is mainly formed of shales and argillaceous schists, which are much contorted and broken; but the prevailing dip is probably to south-west, the beds striking with the direction of the ridge. An obscurely seen trap-dyke seems to observe the same course. To these two facts, the dip of the beds and the existence of the rigid trap axis, the present form of the slope is, I believe, under the influence of subaërial denudation, to be attributed; and not to the “friction of a glacier,” as has been suggested by Mr. H. Blanford (*l. c.*).

It is true that there are no “subordinate ridges and spurs,” but such is not uncommonly found to be the case where valleys run with the strike between hard beds bounding softer ones, which have been eroded to form the valleys.

Towards the end of the ridge, overhanging the Dépôt, limestones, which are clearly seen in section to occur as irregular lenticular masses, not as beds, become somewhat abundant. I shall have to refer to them again presently. The range, on the south-west of the valley of which Iarpathar and Deopathar are the culminating peaks, is formed of massive limestones, the bedding of which is generally very obscure. There is also some trap, the combined rocks giving a very rigid and steep outline to the range, which contrasts most strikingly with that on the north.

¹ Excepting Malwa Tal, which is just outside the boundary.

² These figures are taken from a small table in the N.-W. Provinces Gazetteer, Article “Kumaun.”

³ The highest point is somewhat in excess of this elevation, which is that of the peak nearest to the lake.

All the rocks of this basin, whether shales or limestones, are singularly unsuited to the retention of the minor glacial marks; and if glaciation did take place, it may be from this cause that no such traces are now found.

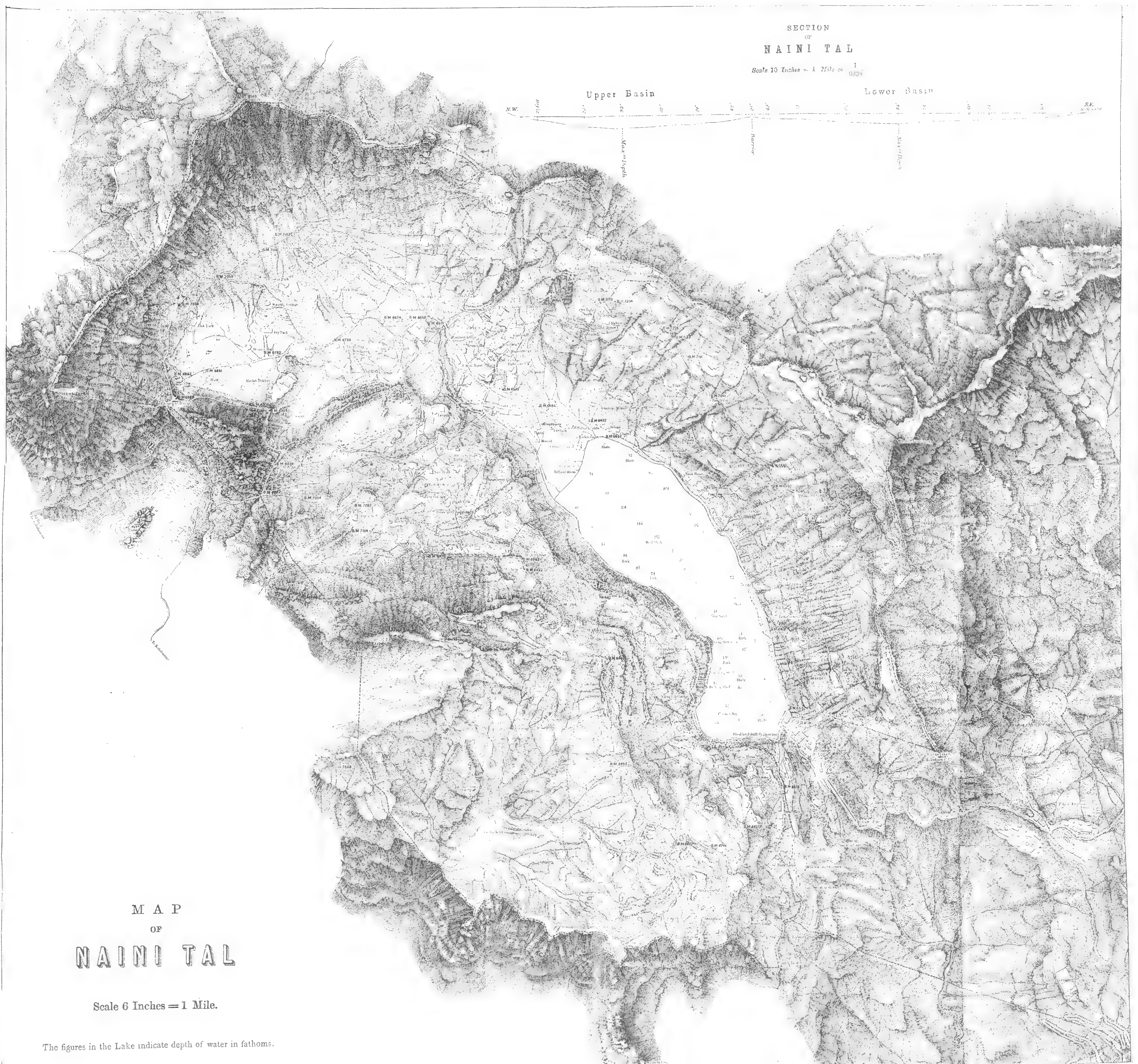
From an inspection of the large scale map, it will be at once apparent that the head of the valley has very much the form of a 'cirque,' as defined by Mr. Helland,¹ who argues with considerable force that the cirques of Norway and Greenland are due to glaciers. Mr. Bonney,² on the other hand, describes Alpine cirques, which he believes to be formed by streamlets pouring down the sides. It has often been remarked how some forms of our Indian alluvia under the operation of heavy rainfalls exhibit in miniature many of the forms of denudation and erosion. Among these forms, cirques and cirque valleys are not unfrequently met with. Invariably, they are due not to denuding action from above, but to subterranean springs or streams. To a similar cause may, I think, be attributed cirque-like valleys in rocks formed of loose shales and, to some extent, even those where the rocks are limestones.

The accompanying section of the bed of the lake indicates a state of things very different from what might have perhaps been anticipated, but, however the lake has been formed, explanations to account for the peculiarity about to be described can be suggested.

The soundings from which this section has been plotted have been taken from the Revenue Survey map on the scale of ten inches to a mile. In some cases the exact character of the bottom is given, but not in all. A knowledge of this character is, no doubt, a very great desideratum for the discussion of this question. It would be especially desirable to know the nature of the bottom all across the lake transversely to this line at the point where the shallowest sounding occurs. As represented in the section, the lake consists of two basins, with the maximum depth nearly centrically situated in each case. They are separated by what appears to be a barrier. If it really be so, then it would lend considerable support to the glacial hypothesis. Indeed, if consisting of rock *in situ*, it would fairly prove the existence of a true rock basin, thus furnishing a strong argument in favor of the glacial origin. Supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier. Unfortunately the case is not susceptible of so simple an explanation, as the shallow sounding may be caused, not by a barrier, but by a mere hummock, which, if (as is possible, so far as is certainly known at present) occurring isolated by deep channels from the margins of the lake, would be on the other hand a strong argument against the glacial origin, as such an obstruction must assuredly have been swept away by a glacier capable of scooping out the deeper hollows. Still another view of the nature of the barrier or hummock, be it which it may, is possible. It may be that it is not really formed of rock *in situ*, but is merely the remnant of an ancient landslip.

¹ "Cirques are large spaces excavated from the solid rock, bounded on three sides by an almost semicylindrical steep mountain wall, and with a tolerably flat floor."—Quar. Jour., Geol. Soc., Vol. XXXIII, p. 161.

² In making these remarks, I labour under the disadvantage of being in camp, away from opportunities of reference to Mr. Bonney's papers.



In the present state of our knowledge, therefore, no certain conclusion can be drawn from it. But the peculiar character of the basin still remains a subject for some speculation, the more particularly so when it is remembered that the operations of the present day must tend steadily to obliterate these features by the deposition of silt in the hollows.

Passing from the lake itself to examine the nature of the barrier at the outfall, we find that it is formed of a confused mass of debris, in which some very large rock masses, some of them ten feet in diameter, occur. Following down the bed of the stream, rock *in situ* is not met with till near the waterfall, or at a level which must be considerably below that of the bottom of the lake where deepest. I had neither the time nor means for actually ascertaining the elevation of the exact point where rock *in situ* is first met with in the stream. But it is an important point to be determined. The result would, I feel confident, completely dispose of any belief in the existence of a rock basin.

Mr. Blanford (*l. c.*), though he does not expressly state his belief that the large blocks of stone are erratics, suggests that they may be derived from the limestone at the ridge at the head of the valley (Deopathar). He states that his "impression was that the lake was closed by a moraine." The source of these blocks I believe to be much closer at hand. In great part they have, I think, simply tumbled down from the Iarpathar ridge and its eastern prolongation, where not only is similar rock to be seen *in situ*, but similar detached blocks are found on the slopes; one remarkably fine example being seen in the compound of Welham house. Others, on the other hand, may have fallen from the ridge to the north of the dépôt, where the already described lenticular masses of limestone occur. The remainder may, I think, have simply been eroded from their envelopment of shales at, or very close to, the positions where they are now found. Though it is convenient to speak here of these blocks collectively as limestones, they vary much in character, and some are highly indurated, but only slightly calcareous, mud stones. From these varying characters it may be possible, hereafter, to trace their origin individually with considerable accuracy. As to the other characters of the debris at the outfall, I in vain searched in it for evidence of a glacial origin, and am unable to point to any feature which is inconsistent with the idea of its having been formed by a landslip.

Further down the valley, near Joli, some 3,000 feet or so below Naini Tal, I observed, when on the road to Ranibagh, that the river has cut through an accumulation of boulders and finer debris to a depth of 200 feet or so, which at the time seemed to me as possibly of moraine origin. On reading Mr. Campbell's opinion of the same kind of deposit near Kalka, which I have also seen, I fear it would require stronger facts than I am in possession of to prove it other than diluvial. I merely mention it here in order to draw attention to the fact of its existence, with a view to its future examination.

BHIM¹ TAL.—This lake is situated about 6 miles, in a direct line, to the east-south-east of Naini Tal. Its elevation is about 4,500 feet above the sea, or 1,900 feet lower than Naini Tal. It lies at the bottom of a valley between two ranges, which strike from north-west to south-east. The northern one is largely

¹ So called after Bhim, Shib or Mahadeo, to whom there is a temple.

made up of greenstone, which I traced from the neighbourhood of Bhuwali, through Bhim Tal, up to Malwa Tal. According to General Strachey's geological map, a continuation of the same outburst extends northwards up to Bhujan on the Kosi. The southern range consists chiefly of quartzites and shales, and rises to a height of 1,300 feet above the lake.

At the entrance to the lake, in the very throat of the gorge, occurs a small hill, about 80 or 100 feet high, which deflects the in-flowing stream, and the existence of which, if it really is, as it appears to be, a stable prolongation of a spur, presents a serious obstacle in the way of a glacial theory. No one can deny, I think, that a glacier capable of scooping out the lake could not have passed over, or on one side of, such an obstruction.

The determination of the fact, whether this hill consists, and to what extent, of rocks *in situ*, is a point, I believe, of crucial importance in this enquiry. Bearing in mind the vast size of the landslips which take place in this region, no one should hastily venture an opinion on such a point. My examination of the ground was of too cursory a nature to admit of my coming to a final decision.

The maximum dimensions of this lake are, length 5,580 feet, breadth 1,490 feet, and depth 87 feet. It is, therefore, the largest, but the shallowest,¹ of all the series herein described.

Whether it be a historical fact or not I cannot say; but it is clearly, I think, a fact that the present outlet of the lake was not the original one. The waters now only escape through a sluice close to the temple, which is situated about midway on the eastern side; but that originally the water found its way out at the southern end, an inspection of the map alone is almost sufficient to determine.

This southern end is now stopped up by what appears to be the debris of a landslide. I was unable to examine the valley below, and the position and elevation of the highest rocks there remain to be determined. At the present outfall, the rocks *in situ* are apparently at a higher level than the bottom of the lake; but this, if it be the case, is a fact of no importance, if my supposition as to the position of the original outfall be correct.

Towards the southern end of the lake, on the eastern side, there is a boulder deposit, which extends along the bank up to a level of perhaps 10 feet above the water. The rounded blocks which it includes were possibly rounded by the waters of the lake when they stood at a higher level, but its appearance suggests a moraine origin. The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslide, the materials must have come from the west, and, of necessity, temporarily filled up a portion of the bed of the lake. As elsewhere, my examination here was very hurried, and I therefore commend this deposit to the notice of future visitors.

MALWA TAL.—This lake is situated about five miles, in a direct line, to the east of Bhim Tal; it lies in a deep valley, which strikes north-west and south-east, and is traversed by the Kalsa river, a tributary of the Gola.²

¹ Sat-tal being excepted as regards depth.

² It is perhaps worthy of note that the drainage of all these lakes is into the Gola river.

The elevations of the parallel bounding ranges on the north-east and south-west average upwards of 3,000 feet above the level of the lake, the height of which above the sea has been approximately estimated at 3,400 feet.

The range on the north is formed chiefly of white and purple quartzites, with which there are some slates and shales. The dip of these beds is variable, but north-west at a low angle seems to be the prevailing direction. Much of the higher face of this range is steeply scarped, but landslips abound, and have, to a great extent, concealed the character of the lower portions.

The range on the south consists primarily of an axis of greenstone, which stretches continuously hence from the neighbourhood of Bhim Tal. Associated with this greenstone are quartzites and shales, the beds in immediate contact often showing signs of much alteration and induration. Occasionally the effect of the former has been such as to cause the affected beds to assimilate to the characters of the greenstone, and to be almost inseparable from it, by mere examination of their outward lithological structure.

What the exact nature of the physical relations of this greenstone may be, has not yet been fully ascertained; but that it does not exist merely as a single simple dyke is amply testified by the fact that branches from it cross the valley at both ends of the lake, and are cut through by the infalling and outfalling streams.

At the head of the lake is a boulder bed through which the river cuts to a depth of eight or ten feet. This deposit consists chiefly of subangular fragments of trap and quartzite. At first I was inclined to attribute it to the effects of a retreating moraine. Temporarily this view was supported by the discovery of boulders of granite and gneiss—no *known* source for which exists within the present drainage limits of the Kalsa. It was impossible, however, to overlook the fact that there were no signs of polishing on any of the blocks, and that those which have come furthest (the granite, &c.) are well rounded and water-worn. Taking into consideration the professedly general character of the only existing geological map, it would be clearly unsafe to adopt the view that no source for these boulders exists within the watershed; and this the more especially as in the adjoining basin of the Gola on the north the occurrence of gneiss and granite is indicated on the map.

The importance of determining the source from whence these boulders have been derived is sufficiently obvious. If they have not come from within the limits of this catchment basin, then indeed it might be necessary to invoke the aid of an ice cap to account for their transport; but in the meantime it is impossible to assert that this accumulation of boulders at the mouth of the gorge is other than a delta of diluvial origin.

Now as to the character of the lake itself. Its maximum dimensions are, length 4,480 feet, width 1,833 feet, and depth 127 feet. Unfortunately, as was the case with Bhim Tal, no series of soundings are available, and the form of the basin is, therefore, uncertain. The bounding ranges and their slopes, however, indicate the **V** (river) rather than the **U** (glacial) type of valley denudation.

Looking up the lake towards the course of the stream, the view just beyond the gorge is quite shut out by projecting spurs, which a glacier could have scarcely failed to modify, if not remove.

At the outfall, no rocks are seen *in situ*. The barrier, now modified by a sluice, appears to be mainly formed of debris thrown down by landslips. The first rock which I detected *in situ* in the bed of the stream was the already mentioned greenstone, which will, I believe, prove to be at a lower level than the bottom of the lake.

As I only had a single day to spend at this lake, I was unable to examine the characters of the wide and unusually straight valley below the village of Malwa Tal (*vide* map); its examination may throw some light on the subject.

NAUKACHIA TAL.—This curiously irregular-shaped lake has received its name from its nine corners. It is situated about one mile and a half to the south-east of Bhim Tal. It occupies a hollow on the slope, and is surrounded by low hillocks, not by pairs of distinct ranges, as are the previously described lakes.

With a very narrow outfall on the north-west, its appearance, as seen from a mile distant, suggested its being little more than a shallow pond. And it did not seem to me to be advisable to curtail my already too short time at the other lakes by paying it a special visit. On returning to Naini Tal, I found, very much to my astonishment, that its depth is recorded at 132 feet, thus being the deepest of the series. If this be the correct depth, it renders the lake one of the most singular of all. Its shape, the nature of its surroundings, and the narrow winding course of the outfall, all seem inconsistent with the view that it is of glacial origin.

Its length is given at 3,120 feet, its breadth 2,270 feet, and its approximate elevation above the sea 4,000 feet.

SAT TAL.—The so-called Sat Tal, or seven lakes, are situated about the same distance to the west of Bhim Tal that Naukachia is to the south-east. They are surrounded on all sides by steep hills, a narrow valley, 100 yards wide, at the outfall of the principal lake serving to carry off the drainage. What the maximum depth may be, I do not know; but two soundings, which I took in the western arm of the principal lake, gave depths of about 58 feet. The artificial dam and sluice somewhat increases this depth over what it would be naturally.

At the outfall there is a landslip, and I do not think any rocks are seen *in situ* till a much lower elevation is reached than 58 feet below water-level.

It is scarcely probable that this group of the seven lakes was in any way formed by glaciers. I have seen in parts of the Central Provinces, where no question of glaciers can arise, denuded hollows among hills, which, if closed by landslips, would form very similar lakes.

Since writing the above, I have received from Mr. Yule, of Bhim Tal, the accompanying plan of soundings, which he has kindly taken in the principal of the Sat Tal at my request.

When it is remembered that this curiously shaped lake has but one narrow outlet, and that it is otherwise surrounded on all sides by hills, but without any considerable catchment area for a glacier to be formed and fed, the difficulty in the way of a glacial theory of origin becomes strikingly apparent.

The maximum depth, it will be seen, is given by Mr. Yule as $61\frac{1}{2}$ feet, so that I must have failed to hit off the deepest part.

Of the smaller lakes enumerated above under class III, I have nothing to say at present. They have not yet been specially examined. Very possibly, there may be in connection with them various points of interest to be yet discovered.

CONCLUSIONS.—Reviewing the whole of the facts which are enumerated above in reference to each of the lakes, and considering the limited zone in which they occur—the probability that they are all the result of one general series of operations impresses itself as being an hypothesis of primary importance. If one of the lakes then exhibits indications which seem to connect it with one particular mode of origin, while others of the lakes do not show such or similar indications, it becomes all-important to submit the former to the severest scrutiny. In this way, I think, the appearances suggestive of a glacial origin, which are perhaps strongest in the case of Naini Tal, lose much of their force when we find that other lakes exist of generally similar character, but in which the special indications are wanting. In the single character of the outfall barriers all the lakes agree; opinions may differ as to the origin of these barriers, whether they are remnants of moraines, or have been formed by landslips; but it is almost certain¹ that not one of them consists in any degree of rock *in situ*, and we therefore have not the positive aid of a rock basin to determine a conclusion.

There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each. Now, I do not think it at all probable that the lakes are due to the original outburst of trap. Indeed, the above described fact in reference to Malwa Tal, where both the inflowing and outflowing streams cut through trap, renders such a view untenable. But it seems not improbable that, when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c., may have been so much crushed and broken, as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of material for landslips, which ultimately served to close the valleys, and form the lakes.² Or even supposing the outburst of trap to have accompanied the upheaval and disturbance, its effect in determining the subsequently established lines of denudation could not fail to make itself felt.

This explanation, in part suggested by Mr. Medlicott's observations in his well known paper on the Alps and Himalayas,³ seems to me more in accordance with the known facts regarding the whole series of lakes, than any glacial theory can be.

¹ Careful levelling can only decide this point.

² It is possible that the basin of Naini Tal may be connected with some local faulting, the existence of which is implied by the sulphur spring at the outfall. That a fault occurs all along the centre of the valley is, however, scarcely probable, as, did one exist, it would show in the scarp of China, the beds forming which appear to be continuous across the head of the valley.

³ Quar. Jour., Geol. Soc., February 1868.

Before commencing examination, I was myself inclined to believe in the probability of a glacial origin; but as my observations have accumulated, I have been constrained to adopt the view, that the balance of evidence available at present is against such an explanation. At the same time, I have indicated that there still remain several points for determination, which are of almost crucial importance. Future observers will, probably, give a large portion of their attention to some of these questions, and, with the aid of the maps, soundings, &c., here given, will be able to add considerably to the above data, thus affording fuller material, by which it is to be hoped a sound and stable conclusion may be finally arrived at.

I have only to add that it appears unadvisable at present to refer particularly here to the debated question, as to the evidence of the former existence of glaciers at low elevations in Kangra and elsewhere.

For the present, the two series of observations had best, perhaps, be kept quite separate, but their ultimate connection and relationship is, of course, none the less obvious.

NOTE ON A TRIP OVER THE MILAM PASS, KUMAON, BY THEODORE W. H. HUGHES, A.R.S.M. F.G.S., *Geological Survey of India*, with a DESCRIPTION OF THE FOSSILS BY DR. WAAGEN, *formerly Palæontologist to the Survey*.

Early in August 1873, an opportunity being afforded to spend a few weeks in Tibet and the higher regions of the Himalayas, my colleague, Mr. Hacket, and I undertook to strike across from Almôra to Milam, and return by the Niti pass. I had once before, in 1869, been through the Milam pass, but I was so distressed by constant pains when at high elevations, that I made no observations worth recording. A judicious preparatory training enabled me on the present occasion to enter the lists, and fight with fair success, against the trials of high-region travelling, and my note-book was brought more into requisition.

The time of year at which we started was too unfavourable to make any other than road-side observations among the lower hills. We were in almost constant rain during our first ten marches, and, however enthusiastic our aspirations in the cause of geology at the outset of each day's journey were, they could not withstand the depressing effect of recurring downpours of water, and we hurried to shelter as the most prudent course to pursue. It was not until we reached the Bhôtia village of Rilkôt, that we passed out of the region of rain.

We were fortunate enough to secure a small collection of organic remains, which, on examination by Dr. Waagen, afforded evidence of the presence of several formations not hitherto detected in this region, and bringing the section here more into correspondence with the sequence of fossiliferous strata established by Dr. Stoliczka in the North-Western Himalayas. To this extent our trip was a satisfactory one; we failed, in that we made no attempt to fix accurately any geological boundaries.

It is easy, however, to reduce within narrow limits the debatable border-land of the fossiliferous and non-fossiliferous rocks, and certain localities can be



referred to their true palæozoic horizon. The main interest of this paper is embodied in Dr. Waagen's remarks; so, after a brief account of the azoic region from Álmóra northward, I will quote them in full, adding a few comments of my own.

We left Álmóra on the afternoon of the 3rd August, and encamped for the evening at Tákli, and on the following day got into Bágésvar, a distance of 30 miles from Álmóra.

The rocks traversed belonged to the metamorphic series, and consisted of quartzites and schists, a few slate bands and some limestones, with a general dip to the north. Good slates occur in the rise of the hill near Billári, and capping the hill is a great mass of limestone.

Where the road slopes to the Sarju river, about four miles south of Bágésvar, soapstone appears. It cannot fail to be noticed in the "rains," from the circumstance that at every step you take down the hill, your feet slip from under you, unless great care be exercised.

Between Bágésvar and Kapkót—the next halting-place, 12 miles distant—similar rocks to those already passed over occur. An impure bed of graphite crops out in the left bank of the first tributary of the Sarju beyond Bágésvar, where the roadway is carried over on a wooden bridge.

From Kapkót we went on to Sháma, a distance of 13 miles. The road leaves the valley of the Sarju at its junction with the Réhra, and follows the course of the latter river. The rocks are of the same character as those seen during the past marches, and have still their northerly dip. Deposits of recent limestone are very prevalent; and at Khar-baggar, where the road to the Pindra glacier leaves the one we were travelling, there is a sulphureous spring.

Our march to Tézam was only 7 miles, but a great deal of climbing had to be done, and we did not arrive until the afternoon. In addition to the ordinary quartzites and schists, and superficial deposits of calcareous tufa which were very numerous, there is a considerable thickness of white dolomitic limestones, compact and very fine-grained. A splendid cliff-section of them occurs at the mouth of the Jánkúli river, which falls into the Rám-ganga, opposite Tézam. Another short journey of $4\frac{1}{2}$ miles brought us to Girgaon, situated high up a hillside. For the first 5 miles the road runs along the right bank of the Jánkúli, and more dolomite is exposed. Near Girgaon talcose quartz-schists replace it.

To Múnshiari,¹ our next halting-place, was 8 miles. The route was a very trying one, owing to the number of heavy ascents and descents. For some way beyond Girgaon the most pro-

¹ Múnshiari is not the name of a village, but the term applied to the whole of the villages that are clustered around Jallat and Súring.

minent rocks are the talcose quartz-schists; but, beyond the ordinary break-fasting place, the name of which I have forgotten, highly garnetiferous micaceous schists are common, and garnets may be picked up in hundreds in little depressions and amongst the roots of trees and shrubs.

We halted one day at Múnshiari, in order to pay a visit to the localities whence are obtained the ovoid stalactites, sold as curiosities to travellers by the people of Múnshiari. The guide took me down to the Góri river, and pointed to places in the cliffs forming the banks, and said they were found there; but I failed to procure any, and I question very much whether I was shown the right spots.

In the neighbourhood of Múnshiari we began to notice a change in the character of the rocks; and on our next march to Lélam we saw some typical gneiss between Dalkót and Tala Dúmár; dip north, at 25°. Opposite Tala Dúmár black mica-schists, in some instances highly garnetiferous, and hornblende schists occur above the gneiss.

From Lélam we marched to Bághdúar, and thence to Rilkót. The road keeps in the valley of the Góriganga, and a magnificent section is exposed of what Dr. Stoliczka terms his central gneiss.¹ It is traversed by granite veins, in the manner described by him.

Still keeping to the valley of the Góriganga, our next halting-place was Búrfú, where we were forced to remain several days until a sufficient number of jabbús (half-bred yaks) had been collected to carry our camp stores and equipage. Búrfú is beyond the ground of the central gneiss, and the rocks between it and Rilkót are quartzites, slates, and schists. Near Tola I noticed an immense number of crystals of iron pyrites in almost all the beds that I examined.

Our first discovery of a fossil was beyond the village of Milam, near Shilong, one of the halting-places of the Bhótias, in some fine silicious sandstone. I think that the *Strophomena aranea*, Salter, which is the only silurian form in our collection, is the specimen referred to; but I am not quite sure, the label having been lost. Along the remainder of our route to the snowy passes, and especially at the foot of Únta Dhúra, we made several additions to our bag of fossils; and each day's journey to the frontier, and through Tibet, enabled us to increase our stock.

Dr. Waagen says of our collection :

"The fossils brought by Mr. Hughes from the Milam pass can be attributed to at least five formations, which are indicated with more or less certainty by the different species. I consider as very probably of cretaceous age some pieces of a flaggy yellowish grey limestone, filled with fragments of shells intermixed with entire specimens, which,

¹ Memoirs, Geol. Surv., India, 1866, vol. V, page 12.

though the species could not be determined, yet, by the association of the genera, indicate with great probability the cretaceous formation. I worked out of those rock specimens—

“*Corbula*, sp., allied to, perhaps identical with, *C. cancellifera*, Stol.; as, however, only one specimen has been found, the determination could not be made with sufficient certainty.

“*Astarte*, a middle-sized species, rather oblique in shape, with concentric folds near the apex, nearly smooth on the other parts of the shells; could not apparently be identified with any of the hitherto described species. This shell seems to fill whole beds with hundreds of specimens.

“*Pectunculus*, sp., a large, smooth, rounded shell, found among the *Astartes*. The species could not be determined, but the occurrence of this genus together with a true *Astarte* indicates nearly with certainty cretaceous beds.

“*Cucullaea*, sp., fragmentary.

“The jurassic formation is represented in the collection, by a tolerably large number of fossils, preserved much in the same way as those found in Spiti.

Jurassic fossils.

“I determined—

Belemnites cf. *kuntkotensis*, Waagen (fragments of the guard)

Oppelia acucincta, Strachey.

Perisphinctes frequens, Opp.

„ *sp. (triplicatus, Stol. non Sow.)*

„ *subineanus*, Opp.

„ *stanleyi*, Opp.

„ *sp.*

Stephanoceras? *wallichii*, Gray.

Cosmoceras theodori, Opp.

„ *octagonus*, Strachey.

Aucella leguminosa, Stol.

„ *blanfordiana*, Stol.

„ *sp. nov.*

Pecten, *sp.*

Rhynchonella, *sp. (varians, Blanf. non Schloth.)*

“The genus to which *Ammonites wallichii*, Gray, belongs is rather doubtful, as no sufficiently well-preserved specimen has been found to make this point certain. *Perisphinctes stanleyi*, Opp., is a very good species, and easy to distinguish from *Perisphinctes cantleyi* and *spitiensis*, with which it has been identified. The new *Aucella* is a large rounded shell, with very few concentric striæ, but it is represented only by a single specimen. Nevertheless I thought it worth mentioning; as the occurrence of a new (a third) species in the Himalayan Jura shows yet more clearly the intermixture of European and North Asiatic types in these jurassic districts. In Kachh already species of the genus *Aucella* are exceedingly scarce, whilst north of Milam some of the rocks are filled with hundreds of *Aucella leguminosa*.”

Almost all the jurassic specimens just described are from the neighbourhood of Laptél. They occur mostly in concretions, in dark-looking slightly carbonaceous shales, that constitute the most distinctive rocks of the formation. At

Laptél the shales overlie limestones, and they form a trough, which has a north-north-west south-south-east strike. They extend southward as far as the halting-place at the foot of the Kíng-rú ghát.

“The different formations of the triassic period are very poorly represented in the collection, but nevertheless the materials are sufficient to state with all certainty the existence of these formations. To the upper Trias very probably belong some hard, flaggy, dark-grey limestones, with millions of fragmentary shells imbedded. However, only on the weather-worn surfaces some species can be recognised, it being impossible to get anything out of the interior of the rock. I am able to recognise one species of *Monotis*, and two species of *Pectens*, on three different rock specimens. The only species determinable, however, is *Rhynchonella austriaca*, Suess.

“There are yet two other divisions of the Trias indicated by fossils in two different kinds of rock. The one is represented by two fragments of Ammonites of the group of *Ammonites semipartitus*. They are preserved as black nodules in a hard, dark-grey, silky, slaty shale, which very likely belongs to the ‘Muschelkalk’ formation. The other division of the Trias is indicated by a small specimen of a badly preserved *Ceratite*, somewhat like some species of the Salt Range, and thus possibly out of some ‘Bunter Sandstein’ beds. The rock in which it is preserved is a hard, red, crypto-crystalline limestone.

“These few fossils, though badly preserved, and specifically not determinable, yet show beyond a doubt the existence of a rather complicated group of triassic rocks.”

There are two geographical zones of this and the underlying series, one being south of Laptél, and the other north of it, in the direction of Kanchégo.

“The next older formations, permian and carboniferous, are represented in the collection by a somewhat better suite of fossils. The most fossiliferous bed is a white limestone with a great number of fragments of crinoid-stems, and the following determinable species:—

Permian and carboniferous fossils.

“*Terebratula himalayensis*, Dav.

“ „ *subvescicularis*, Dav.

“ „ *sp. nov. ?*

“*Athyris roissyi*, L'Ev.

“*Spirifer cf. glaber*, Martin.

“*Camerophoria*, *sp. nov. ?*

“*Productus semireticulatus*, Martin.

“ „ *sp.*

“*Bactrynum* *sp.*

“*Cyathophyllum* *sp.*

“It is very interesting to trace how much this fauna resembles that of the lower carboniferous limestone in the Salt Range; and even the preservation of the specimens is such, that they could be mistaken as coming from the Salt Range. *Productus semireticulatus* occurs of its typical size, whilst the small form from Spiti, which is found also here, and quoted by me as “*Productus*, *sp.*,” is very likely a different species. The latter, however, has been also obtained, though rarely, from the Salt Range.

“The *Camerophoria* quoted above is a beautiful large species, which I could not determine for the present. The *Bactrynum* also is interesting, which is found plentifully in identical specimens in the Salt Range. The genus has been described by Gumbel after a very small species out of the ‘Kössener’ beds of the Bavarian Alps. The zoological relations of the genus, however, are as yet thoroughly unknown.

“Other beds, possibly also of carboniferous age, which, however, could not be ascertained by the few fossils obtained from them, have furnished :—

Rhynchonella, sp.

allied to *Rh. acuminata*, Martin, preserved in a black hard shale, and

Spirifer cf. *striatus*, Martin,

Stringocephalus ?? sp.

Rhynchonella ? sp.

all bad specimens, preserved in a dark liver-coloured limestone.”

The dark-coloured limestone is very probably of carboniferous age, as it came from the same locality as the rocks which furnished the fossils of undoubted carboniferous affinities.

“Of all the silurian formations, there is only one specimen of rock in the collection, consisting of a bit of white not very hard sandstone, with manganese specks, upon which several casts of *Strophomena aranea*, Salter, are observable.”

Silurian fossil.

The sandstone in which this brachiopod occurs comes, as well as I can remember, from the neighbourhood of Shilong, as already mentioned.

The following list of halting-places and distances from Álmóra to Milam may be useful :—

Name of halting-place.				Distance.	Remarks.
1.	Tákli	...	...	16 Miles.	No resting-house.
2.	Bágés-war	...	...	14 "	Dák bungalow.
3.	Kapkót	...	...	12 "	Dharamsála.
4.	Sháma	...	...	13 "	Ditto.
5.	Té-zam	...	...	7 "	School-house.
6.	Girgaon	...	...	6½ "	No resting-house.
7.	Múnshíari	...	...	8 "	Dharamsála.
8.	Lé-lam Thánkót	...	...	6 "	Cave.
9.	Bághdúar	...	...	8 "	No shelter.
10.	Rúlkót	...	...	8 "	Ditto.
11.	Milam	...	...	8 "	Ditto.
TOTAL				106½ "	

THE MUD VOLCANOES OF RÁMRI AND CHEDUBA, *by* F. R. MALLET, F.G.S.,
Geological Survey of India.

During a recent tour through Rámri and Cheduba, the main object of which was to examine and report on certain coal-beds said to exist in the islands, I had an opportunity of visiting the greater number of the mud volcanoes, the occurrence of which has long been known, and brief allusions to which are to be found in many standard works on volcanic phenomena and on general geology.

The original sources of information referred to in such works consist mainly of a "Report on the Island of Chedooaba" by Commander E. P. Halsted,¹ which, amongst other matter, contains valuable and, with but few exceptions, accurate observations both on the volcanoes, and on the elevation of Cheduba and the neighbouring islands which has occurred within the last two centuries. Besides the above, a few notes on the volcanoes of Rámri may be found in Lieutenant Foley's Journal of a tour through that island, and in a paper on some coal which had recently been found at Kyauk Phyu.² Dr. Spry, also, has briefly alluded to one of the volcanoes near the last named place in his account of "A three weeks' sail in search of health."³ Notices by Captain J. Russell of a volcanic island which rose from the sea near Cheduba in 1843 and subsequently disappeared; of a fire at sea witnessed from Kyauk Phyu in 1845, and conjectured to have been volcanic; and by Major Williams of an eruption from one of the Kyauk Phyu volcanoes in 1846, have also been published.⁴ To all the above records I shall subsequently have occasion to refer.

The allusions to Rámri and Cheduba by systematic writers refer mainly to the fact of the mud volcanoes there being at, or near, the end of that great line of volcanic vents which may be traced thence southwards by Narkondám and Barren Islands, in the Bay of Bengal, through the entire length of Sumatra, Java, and the eastern islands of the Sunda group. By some, indeed, this line is considered only a portion of a still greater one which, stretching from Tierra del Fuego northwards, along the western fringe of South and North America, is continued through the Aleutian Islands, Kamschatka and Japan to the Phillipine and Molucca Islands. There it is considered to divide into two, one branch running south-east through Papua, the New Hebrides and New Zealand; the other passing, as before said, through Java and Sumatra, and having its furthest limit in Arrakán and Chittagong.⁵

¹ Journal As. Soc., Bengal, X, 1841, pp. 349, 419.

² *Ibid.*, II, 1833, p. 595; IV, 1835, p. 20.

³ Journal As. Soc., Bengal, X, 1841, p. 138.

⁴ *Ibid.*, XII, 1843, p. 1114; XIV, 1845, Proceedings for February; XV, 1846, Proceedings for November.

⁵ Scrope on volcanoes, p. 12; Lyell's principles, 10th edition, II, p. 585. There is a 'true' volcano, called Puppá-doung, about 30 miles east of the Irrawádi, in latitude 21°, but it has been long extinct. It has been described by Mr. W. T. Blanford, who believes it to be of Miocene or Pliocene age; more probably the latter (Jour. As. Soc., Bengal, XXXI, 215).

Orographically and geologically, however, the islands in question, which,

Physical features of Rámri with the islets in the neighbourhood, may be conveniently spoken of as the Rámri group, are intimately connected with the Arrakán range of mountains, which, running from Cape

Negrais northwards towards Manipur, forms the dividing ridge between the basin of the Irrawádi and the smaller rivers of Pegu, Arrakán and Chittagong, which find their way direct into the Bay of Bengal. In the latitude of Rámri this range attains in places an elevation of from three to nearly five thousand feet, the hilly islands in question constituting outliers on the western flank of the range. Rámri is separated merely by a narrow creek from the mainland, to which the whole group would be connected by an elevation of a few fathoms.¹

No map is in existence which correctly delineates the orographical features of these islands. The Rámri hills are disposed in very numerous, and generally irregular, ridges. In some cases, where bands of harder rock preserve a uniform dip and strike, as between Likmau and Minbain, straight and well defined ranges occur, but more frequently, owing to the irregularity of the strike and dip, and the softness of much of the rock, the hills are irregular in their direction and featureless in outline. There is, however, a general tendency to a direction approximating to north-west—south-east. Generally the rounded, jungle-clad ridges vary in height from one or two hundred feet to double or treble that elevation. The hills in the southern part of the island are, on the whole, higher than those further north. Lieutenant Foley estimated the height of Jika, a hill not far from the coast, to the south or south-south-west of the town of Rámri, at 3,000 feet, but this requires confirmation. The highest Revenue Survey Station on the island is about 700.

Between the various ridges, and stretching to either side of the tidal creeks by which the island is intersected, are alluvial flats which are often of large area, and taken together constitute an important proportion of the island. As an illustration of the extent to which the latter is penetrated by such creeks, it may be mentioned that, at high tide, boats of 10 or 12 fathoms length can go up the Minyát River to the village of the same name, which is within less than two miles of the western coast.

My acquaintance with Cheduba is confined to the eastern side. Captain Halsted, however, who surveyed the island, describes the general features thus: "Its general appearance and character is that of a fertile well-wooded island of moderate height, and irregular outline. A band of level plain, but little raised above the sea, extends around its coasts, of far greater width on the east than on the west; within this lie irregular, low, undulating hills, varying in height from 50 to 500 feet, enclosing several higher detached mounds of steep, well-wooded sides, the loftiest of which, near the south part of the island, rises nearly 1,400 feet."²

The larger of the outlying islands are very similar to the main ones, on a smaller scale; low rounded hills from 100 to perhaps 300 feet high rising from cultivated alluvial plains.

¹ *Vide* Admiralty Chart of Bay of Bengal, 1876, sheet 4.

² On the map of the province of Pegu, scale 8 miles=1 inch, published in the Surveyor General's Office, 1856, a hill, presumably that alluded to by Captain Halsted, is marked 1,700 feet.

The evidences of recent elevation, visible along the coast in many parts of these islands, are patent at a glance. The southern portion of Round Island is occupied by a little rocky table-land 100 or 150 feet high, and the remainder by a plain elevated but a few feet above the sea. A portion of the latter is composed of rounded pebbles and boulders of rock, lumps of coral, sand and broken shells—a raised sea-beach. The remainder is an alluvial flat, formerly doubtless a mangrove swamp, but now occupied by rice-fields, amongst which are some large rocks with marine shells still adhering to them. At the northern end of the island there is a detached rock on the beach which strikingly illustrates the elevation, crowned, as it is, by an aggregated mass of marine shells, the base of which is about six feet above the present high tide level, and the upper surface covered with grass and shrubs (*vide* illustration). Rocks of a similar kind are also to be found elsewhere on Round Island, as well as on Regnain, or Flat Island, to the south. A map of the latter is appended to Captain Halsted's paper, showing the present island to consist of three terraces differing from each other in level by six or eight feet, *i. e.*, 1st, the original island (containing a mud volcano in its centre) previous to the elevation, which is said to have taken place about the middle of the 17th century; 2nd, the island after this occurrence; and 3rd, the present island, the outer portion of which was raised about the year 1750¹ according to native information obtained by Captain Halsted. The last elevation was accompanied by a very violent earthquake: in Cheduba "the sea washed to and fro several times with great fury, and then retired from the grounds, leaving an immense quantity of fish, the feasting on which is a favorite story throughout the island; no lives were lost, no rents in the earth occurred, nor fire from the volcanoes of the island." It has been suggested by Mr. Piddington (native villagers not being very accurate, generally, as to dates) that the earthquake was coincident with the submarine volcanic eruption described as having occurred off Pondicherry in 1757², and, with much more probability, by Lieutenant Baird Smith, to have been the same earthquake as that which partially destroyed Chittagong in April 1762, and which was felt throughout Bengal, Arrakán, and Pegu.³ A comparison of Captain Halsted's map of Flat Island with the present shore line indicates no further elevation since the date of his paper.

His measurements show the total elevation to have been 9 feet at Foul Island, 50 miles south-east of Cheduba, from 12 to 22 feet in various parts of Cheduba itself, and 13 feet at the Terribles, west of Kyauk Phyu; the elevation having been greatest towards the north of Cheduba, and declining both to south-east and north-west. Evidences of the inequality of the elevation are also to be found in Rámri. On the western coast, between Konbaung and Kyauk Galé (and doubtless further) there is a raised beach about 20 feet above

¹ Ninety years before 1841 according to the text, which refers to Cheduba. On the map of Flat Island the last elevation there is stated to have occurred eighty years before the same date, but this would appear to be a clerical error; there is no allusion in Captain Halsted's paper to a difference of ten years between the last elevations of Cheduba and Flat Island respectively.

² Trans. Bombay Geographical Society, X, 146.

³ Journ. As. Soc., Bengal, XII, 1050.*

the sea, strewn over with worn lumps of coral, and of rock bored by *Pholadidæ*¹, whose shells still remain in the holes. But a large part of the alluvial area on the eastern side of the island, not more than a few feet above the sea, does not exhibit such evident signs of recent elevation, nor does there appear to be any tradition of such large proportion of the island having recently emerged.

The elevation at the Baránga Islands has been comparatively slight. In one place, however, at the north end, I observed oysters sticking to the rock about two feet above spring high water mark. Further north again, the effects of the great earthquake of 1762 were of a precisely opposite character, large areas in the Chittagong District having been then *submerged*.²

The rocks are of a very similar character throughout the islands, consisting almost entirely of shale and sandstone. The former
 Geological character. is of different shades of gray; although sometimes well bedded, much more frequently it is clunchy, and not uncommonly passes into clay. Almost everywhere it includes numerous large irregular nodules, or short strangulated beds, which are more or less calcareous, and some of which are tolerably pure limestone. These nodules are often traversed by strings of calespar. Irregular strangulated veins of the same mineral also intersect the shales themselves, in places, and the latter are occasionally gypsaceous, containing small disseminated crystals of selenite, which, by the weathering away of the shales, become scattered about on the surface of the ground. Small nodules of clay-ironstone are also met with in this way, but are not very common. Shales of the above varieties constitute an important proportion of the entire bulk of the rocks.

The sandstones are usually gray or greenish-gray, more rarely yellowish or pure white; sometimes harsh; generally moderately fine-grained, and often tolerably hard. Sometimes they are intersected by veins of calespar, or, like the shales, contain irregular nodular calcareous masses. Conglomeritic beds, containing pebbles from two inches diameter, downwards (which are mainly of white quartz), are met with, but rarely, and of trifling thickness.

Both shales and sandstones not unfrequently contain lignite. It occurs in little irregular strings, or in strangulated layers from an inch, or less, up to three or four inches thick, and seldom as much as a foot long. Where these are found they generally occur more plentifully in some beds than others, lignitiferous strata being interbanded with others which contain no carbonaceous matter. Woody structure is frequently seen in such layers, which are often merely the ends of stems that have been crushed flat. Sometimes the stems are only partly converted into lignite, the remainder being silicified, although still black from residual carbonaceous matter. In some cases the lignite contains pyrites. Much larger stems than the above are occasionally met with, one or two that I saw being 18 inches in diameter, and visible for a length of six or seven feet, but they are far from common of such dimensions.

True seams of coal have also been found—at Tsétamá, in the southern part of Rámri, where several outcrops occur, varying from one to six feet thick;

¹ For this determination I am indebted to Mr. W. Blanford.

² Journ. As. Soc., Bengal, XII, 1013.

and near Pallang Roa in Cheduba. Beds of more or less carbonaceous sandstone have been met with in one or two other places. As I shall subsequently have occasion to describe these coal-seams in detail, with reference to their economic value (p. 207), it is unnecessary here to do more than mention their occurrence.

Besides the above strata, some bands of limestone of considerable thickness are to be found, which will be subsequently more fully described (p. 221). One of the most important of these is near Yánthek, where the rock bears some resemblance in aspect to a coarse yellowish-white chalk, but does not mark like it, being as hard as ordinary limestone. It is rather brittle, breaking with a tolerably smooth fracture. The bedding is generally obscure, and masses up to 20 feet thick occur in which none is apparent. A limestone of very similar character also occurs near Tsinbok. In the Pagoda Hill, at the town of Rámri, and again a mile or two further east, a thin band of such rock occurs interbedded with sandstone and shale of the usual type. South-east of Tsétamá limestone of a different character occurs. It is of a pale gray or grayish-white color, rather hard, not brittle, and instead of the chalky look of the above, has a minutely crystalline structure. It is very massively bedded, and there are, apparently, at least two bands, each not less than 25 yards thick, with sandstone between. At Tengbain similar minutely crystalline limestone is associated with rock of a much coarser grain, which in hand specimens is not unlike some varieties of limestone from the old metamorphic series. Such crystalline limestone, again, at Allé Chaung and Tsáné, is associated with grayish chert, which is very cellular and rusty on the weathered portion, and is intersected by very numerous strings of white quartz: some surfaces of the rock are sprinkled with little limpid rock crystals. Cherty and calcareous seams are irregularly interbanded with each other, the beds with which these rocks are associated being ordinary sandstones. Similar chert, with or without accompanying limestone, is met with not unfrequently elsewhere, but the bands do not appear to exceed a few yards in thickness.¹

With the exception of the limestone associated with chert at Allé Chaung, which is dolomitic (and contains minute crystals of magnetite disseminated through it), all the limestones I have examined are purely calcareous.

The rocks, generally, throughout the islands, have been greatly tossed about, the strike being far from constant, and the dip extremely irregular. Not unfrequently it is vertical. But owing to the softness of the shales, and their clunchy character, and the facility with which much of the sandstone gets broken up superficially, the lie of the rocks is often very obscurely seen.

It would be certainly rash, on the strength of such a cursory examination as mine, to assert that the rocks throughout the islands belong exclusively to one series, but as far as my observations go, they do not suggest any grounds sufficiently strong for attempting a separation.

The only fossils I observed were some obscure markings in the sandstone at Likmau, and there is so much lithological resemblance between some of the tertiary groups of Burma that little can be gleaned as to the age of the Rámri rocks from their mineral characters. It may be remarked, however, that

¹ Mr. W. Theobald mentions similar chert as occurring in Negrais and nummulitic strata of the Pegu Division: Mem. G. S. I., X, 300.

petroleum-bearing rocks occur throughout the islands, and that the oil-bearing rocks of Pegu, which are within 70 miles of Rámri in a straight line, are believed by Mr. Theobald to be nummulitic, all the known oil localities being situated either on nummulitic or still younger strata.

Again, the coal hitherto found in Eastern India (Assam and Burma) is all either of cretaceous or of nummulitic age, the former being markedly different in external characters from the latter.¹ That from the Rámri Islands bears no resemblance to cretaceous coal, and is quite of the nummulitic type.²

The number of mud volcanoes distributed over the islands is considerable, there being in Rámri itself a dozen or more; more than half that number in Cheduba³; three, at least, on Amherst, and two on Flat Island. I have heard of others on the neighbouring part of the mainland, but have no definite information about them. On the opposite side of the Arrakán Range, near Menbo, on the Irrawádi, numerous mud volcanoes exist, which have been described by Dr. T. Oldham,⁴ and two are mentioned by Mr. W. Theobald as occurring on the coast not far from Cape Negrals.⁵ I myself observed a very small one in the Baránga Islands, and there are records of two sub-marine eruptions. It was reported, on native information, that two volcanoes opened in the Chittagong District during the earthquake of 1762.⁶ It would appear, therefore, that salses are rather widely distributed over both flanks of the Arrakán Range. But those in the Rámri group hold the first place in magnitude and in the violence of their paroxysmal eruptions. It will be observed that they illustrate, on a small scale, that distribution into linearly arranged and isolated vents which has been so commonly remarked amongst the great volcanoes of the earth. At Kyawk Phyu six occur in a line within a distance of perhaps a mile and a half along the summit of a low broad ridge. Two volcanoes in close proximity, or with their circumferences even touching each other, occur in several cases elsewhere.

In respect to their form the volcanoes may be divided into *mounds* and *cones*, there being, however, no sharp line between the two varieties. The former are approximately circular, generally varying in diameter from 50 to 100 yards with a height of perhaps 15 to 30 feet; there are, however, two exceptionally large ones in Cheduba, south-east of the Pagoda Hill, respectively about 200 and 250 yards across. The mounds look like an accumulation of angular fragments of rock—shale, sandstone, &c., but this appearance is deceptive. During ordinary times mud is ejected in small quantities, and during the greater eruptions, stones and mud are shot out together, the whole forming a sort of unconsolidated conglomerate. The wash of rain, however, scours

¹ Memoirs, Vol. VII, p. 175.

² The limestone at Yánthek and Tsinbok (p. 221) apparently closely resembles that described by Mr. Theobald at p. 313 of his report, and which he considers to be cretaceous. That some of the Rámri rocks should be referred to this age is by no means improbable.

³ Vide Captain Halsted's Map, Journ. As. Soc., Bengal, Vol. X, p. 446.

⁴ Mission to the Court of Ava; by Captain Yule, 1855; Appendix. p. 339.

⁵ Mem., G. S. I., Vol. X, p. 119.

⁶ Journ. As. Soc., Bengal, XII, 1050, and Phil. Trans., LIII, 25E.

the mud away from the surface, leaving a superficial layer of fragments behind, which thus have the appearance of constituting the whole mass. On digging down a foot, or less, the true composition becomes apparent. There are often cracks, also, which show the mud below, sometimes in a dried, in other cases in a still pasty condition. In the centre of one of the Kyauk Phyu mounds there was a circular space, about 10 yards diameter, where the surface crust, composed of fragments cemented by dried mud, was not more than 9 inches thick, and was intersected by numerous shrinkage cracks through which a ten-foot stick could easily be thrust into the soft mud beneath. The highest part of the mounds is generally at or near the centre, but not always. One of the large mounds south-east of Pagoda Hill has its summit about halfway between the centre and circumference. Scattered over the mounds, more commonly towards the central part, but sometimes at or near the edge, there are generally a few mud cones from a few inches to as many feet in height, with craters at the top containing more or less liquid mud. To these I shall allude again.

The mounds, which are quite bare of vegetation themselves, are surrounded by a ring, varying in breadth, but averaging perhaps 50 to 100 yards, of casuarinas, not very thickly grouped, and unaccompanied by any other trees. Beneath them is thinly scattered grass. Immediately outside this ring the ordinary jungle commences. Casuarinas are only found in the islands along the sea coast and around the volcanoes. They prefer a saline soil, which they obtain in both positions. The mud ejected from the volcanoes is invariably saline, and while favouring the growth of casuarinas, prevents that of ordinary jungle. At the two large salses south-east of Pagoda Hill (and in this case only, as far as my experience goes) the casuarina ring is replaced by one of phoenix palms.

The most perfect examples I have seen of the conical form of volcano are the two salses at Kyauk Phyu nearest the sea. One of these is about 40 feet high from the inner side of the casuarina ring,¹ with a slope increasing in steepness towards the top of the cone, where there is a crater 12 feet in diameter, filled, (at the time of my visit), to within 4 feet of the top, with thickish mud into which a stick 10 feet long could easily be thrust. The other cone is similar, but smaller.

Mounds are commoner than well developed cones. The former would appear to be in an earlier stage of development. The difference in form is partly caused, also, by the mud ejections in the former case shifting their positions at different times to different portions of the mound. Thus at one of the salses south-east of Pagoda Hill, the largest mud craters at present, one of which is 10 feet high, are situated close to the edge of the mound. When such a change of position takes place, the deserted craters, which have not had time to attain any very large dimensions, are washed down by rain into the general mass of the

¹ Owing to the weathered, broken up, condition of the shale and sandstone in the low broad ridge on which the volcanoes are situated, it is rather difficult to distinguish the debris of the former from that ejected from the volcanoes, or to determine how far the ridge has been produced by the latter. The summit of the last mentioned cone is 200 or 300 feet above the sea. Captain Halsted says that the volcanoes in Cheduba vary from 100 to 1,000 feet above the sea level. These elevations, however, include those of the hilly ground on which many of the volcanoes are situated.



Model A and Model B are also compared with the results of the two-stage model.

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mound, so that the latter presents, as before described, the aspect of a heap of stony debris on which only the more recently formed and active mud cones remain. On the whole, however, the ejections are generally more frequent, or more abundant, towards the centre of the mound, which is consequently highest. Occasionally, however, the summit is found elsewhere.

In the case of the second form, the ejections (of sufficiently viscid mud) have remained constant to a single vent, around which the entire mass of matter has by degrees been built up into one cone of regular outline. In the character of the ejected stones, the surrounding casuarina ring, &c., the cones are quite similar to the mounds.

On rare occasions the mud volcanoes are subject to paroxysmal eruptions of great violence. In ordinary times, however, they remain in a state of comparative quiescence. Sometimes action is suspended altogether, but generally a few mud cones, from a few inches to as many feet high, are scattered over the mounds, in the majority of cases at or near the centre. The craters at the top contain mud in various degrees of fluidity. Sometimes it is thin and watery; in other cases thick and viscid. The thin mud forms cones of very regular outline, but low inclination; sometimes not more than 15 degrees: the cones produced from viscid mud, on the contrary, rise at steep angles, and are sometimes nearly vertical at the top. In such cases they are formed, in part at least, by small quantities of mud *spirted* out, which drop back on the rim and gradually build it up like a wall. Bubbles of inflammable gas rise through the mud in the craters, when they are active, in greater or less number. When the mud is very thick the gas issues with a peculiar 'clucking' sort of noise, and when sufficiently forcible, produces the spirting just alluded to.

Besides such spirtings, flows of mud issue at times from the craters, generally finding an exit by breaking down the weakest part of the rim. A stream of some magnitude had flowed from the most northern of the Kyauk Phyu conical volcanoes not long before I visited it. Issuing from a gap in the crater wall, with a breadth of 18 inches or 2 feet, it flowed down the side of the cone, with a very constant width. At the bottom it got into a small channel, and continued its course for a distance of 100 yards from its source. The stream well exhibited that canal-like form which sufficiently viscid mud assumes under such circumstances. Owing to the sides moving more slowly than the centre, and hence having more time to dry, the mud there first becomes too consolidated to flow further, and forms banks between which the central portion still flows on. An analogous phenomenon is frequent in lava streams. "A stream of lava," says Mr. Scrope, "while flowing down any slope, will, owing to its imperfect fluidity, usually be thickest towards its centre, and consequently possess a convex cross section on its upper surface, the sides rising as steep banks from the uncovered ground adjoining. But when the supply of fresh lava from the vent diminishes or entirely ceases (the still liquid interior at the central part of the current continuing for some time to flow on, urged by its own weight above, down any slope that offers itself), the upper crust, being unsupported, will have a tendency to subside in proportion. Hence we often find narrow lava-streams confined

within banks, which they seem to have raised themselves, and having a *concave* surface in their cross section; the sides, which necessarily cooled sooner than the central part, preserving their thickness, and taking the form of high banks or ridges, between which the internal lava-stream flowed on for some time, as in a canal, the level of its surface gradually lowering as the supply from above ceased."¹

The sources of the mud are undoubtedly the gray shales which form such an important part of the rocks throughout the islands. Although these are generally brittle and clunchy in a dry state, when thoroughly soaked with water, as they are seen, for instance, along the shore at low tide, they break with a somewhat plastic mode of fracture, and are easily kneaded into mud identical in appearance with that ejected from the volcanoes.

I have not myself observed the mud to possess any sensible degree of warmth, but I was not fortunate enough to witness any actual eruption beyond a mere dribble. That the mud is warm, however, at times, we have the evidence of Mr. Howe, who found "a hot slimy fluid" some time after a fiery eruption from one of the Kyauk Phyu volcanoes. Captain Halsted found mud brought up from a depth of 17 feet at one of the Rámri volcanoes to show "a temperature of 92° 20', above that of the atmosphere" (*sic*; misprint for 92°, 20° above that of the atmosphere?). Dr. Spry also remarked that the crater of one of the Kyauk Phyu volcanoes, 12 feet in diameter, "was filled with warm liquid mud."

The ejected mud always contains more or less saline matter, which is principally common salt. Occasionally, however, this salt is mixed with a large proportion of sodium sulphate, and contains calcium sulphate besides. It has been suggested that the salt is derived direct from sea water;² and Captain Williams even mentions having received a fish which was *said* by the natives to have been thrown up by one of the Kyauk Phyu volcanoes.³ This idea, however, is scarcely supported by the want of uniformity in the composition of the salt, and it is, I think, probable that the latter is derived in considerable part from the rocks themselves that yield the supply of mud. The intimate connection between the petroleum and mud volcanoes of Rámri will be subsequently alluded to, and it is well known how frequently mineral oil and salt are associated. In India they are found together in the oil-producing tracts of Burma, Assám, and the Punjáb.⁴ That the Rámri rocks do contain saline matter I found by examining the shales or clays from the oil-wells of Tsi Cháng, Létaung, and Minbain, which when lixiviated with water all yielded soluble chlorides and sulphates in varying proportions. Further, it appears from Dr. Oldham's account that the mud from the craters at Menbo on the Irrawádi, some 70 miles from the sea in a straight line, is saline also, and is largely used for the preparation of salt by lixiviation.

Water in considerable quantity is, of course, a necessity for the production of the often slushy mud ejected by the Rámri salses, and that this in some

¹ Volcanoes, p. 76.

² Trans. Bombay Geol. Soc., X, 146.

³ Journ. As. Soc., Bengal, XII, 334.

⁴ Rec. G. S. I., VI, 70; Mem. G. S. I., XII, 356; XI, 129.

cases infiltrates from the sea is by no means unlikely, but in others, where the volcanoes are two or three miles from the coast or any creek, it would appear not improbable that the water is derived from surface percolation. Saltness is a very common characteristic of mud volcanoes, as is indeed indicated by the term *salse*¹ often used for them.

Although the emissions from the volcanoes in their ordinary condition are of the above described insignificant character, at uncertain (and sometimes long) intervals, eruptions of a much more violent character take place. At such times mud and stones are shot out with great force and noise, accompanied by large quantities of inflammable gas, which in many cases catches fire and gives rise to a volume of flame that lights up the country for miles around. Of course such eruptions vary in intensity, some being much more violent than others. I was not fortunate enough to see anything of the kind, but there are several records of their occurrence.

From one of the Kyauk Phyu volcanoes, Dr. McClelland states, that "vapour and flame were seen by the inhabitants of Kyauk Phyu to issue to the height of several hundred feet above the summit during the principal shock of the earthquake of the 26th August 1833²." This was a violent earthquake felt, amongst other places, at Calcutta, Agra, Nepal, and Lássa.

On the 23rd of March 1839 a very severe earthquake was felt throughout the whole of Burma, during which "fires, mingled with smoke and ashes, rose to a fearful height" from one of the same group of vents.³

Mr. Howe, Marine Assistant at Kyauk Phyu, thus describes an eruption which occurred on the 6th of February 1843:—"We had, last night, a most magnificent volcanic eruption. The mountain, which is of moderate height, and shaped somewhat like a pyramid, is about three or four miles from the station, which was rendered as light as noon-day, though midnight at the time. The eruption commenced at about 11 P. M., unaccompanied by any rumbling, but throwing up masses and particles of lava (*sic*; *vide* p. 202) to an immense height, and presenting a most magnificent spectacle, visible all round the country. The weather had been for some evenings previous close and threatening, though the glass kept up, varying from 30° 12' to 29° 98' for the last five or six days.

"The fire gradually went out, and all was still again by about half an hour after midnight.

"This eruption takes place, from what I hear, generally once in two years, sometimes annually."⁴ Subsequently—how long does not appear—Mr. Howe wrote,—“The volcano is still in a bubbling boiling state, the orifice not larger than a tea cup, and there is a hot slimy fluid to be dipped up at the surface, but no vapour or noise is emitted, and it is otherwise quiet.”⁵ As no vapour was emitted

¹ From *salsus*, salted.

² Report of a Committee for investigating the coal and mineral resources of India (1838), p. 41.

³ Silliman's Journal, XXXVIII, 386—British Association Earthquake Catalogue.

⁴ Journ. As. Soc., Bengal, XII, 256.

⁵ *Ibid.*, 521.

the "boiling" spoken of was doubtless the escape of gas. The orifice must of course have been of considerable dimensions during the eruption on the 6th of February. Subsequently to that date, when the violent stage of the eruption was over, a mud cone, similar to those described above, was probably quietly built up over the spot, with a crater of the size mentioned.

Between the 26th and 29th of July 1843, an eruption took place "at a distance of about thirty bamboos" south of False Island, which a few months afterwards was described as follows by natives of Cheduba and Flat Island to Captain Russell, commanding the H. C. steamer *Ganges*: "About our morning meal, or 7 or 8 o'clock on the morning of the first day, we heard a great noise, and saw fire rising out of the sea, which continued for four days; on the second day we saw a small island newly formed in the sea, between 'Flat Rock' and 'Round Rock,'¹ about the size of the sandbank called False Island.

"We saw the newly formed island for a month, but could not approach it on account of the boisterous sea on the coast. We felt an earthquake before we saw the fire in the sea; in the month of October we came out in our boats to look for the island, but saw nothing. The rocks, as they now lay, are of the same number and position as before the appearance of the new island."² Captain Russell found two and a half to three fathoms of water over the spot where the island had been, with a rocky bottom. The ejecta during such eruptions being exclusively mud and stones, none but the largest among the latter would have any power of resisting the waves during the south-west monsoon.

"On the night of the 2nd of January 1845," Ensign G. Hankin, 66th Native Infantry, wrote, the day after the occurrence:—"Between the hours of 6 and 7, a very interesting and singular phenomenon was observed off the coast of Kyauk Phyu. The sky on the horizon was observed to brighten up as when illuminated by the rays of the setting sun, except that the light more resembled the flickering of a fire than the gradual descent of that luminary. It continued in this way for half an hour or so, when all of a sudden immense volumes of flame were seen to issue as it were from the depths of the ocean, presenting the most sublime yet awful spectacle to the beholders. The general idea entertained was, that a ship had caught fire; but this was soon dispelled by a low continuous rumbling, which seemed to sound from the bowels of the earth, and was re-echoed by the surrounding hills. Previous to this, however, Captain Howe, the Marine Superintendent, had with the greatest promptitude set off in H. C. schooner "*Petrel*," intending to render assistance to the supposed unfortunates of the burning ship; he returned without seeing anything, and it is thought that the whole was the result of some hidden volcanic agency; one of the neighbouring hills possessing that extraordinary property, and from which flames have been seen to issue before. The weather at the time was still and serene, hardly a breath disturbed the air: it was in fact, as some one observed, a very earthquaky day."³ According to Captain Williams' account "the reflection of the flame was made on a dark bank of clouds, west of the station, on the track of ships from hence

¹ Not to be confounded with Flat and Round Islands.

² Journ. As. Soc., Bengal, XII, 832, 1116.

³ Journ. As. Soc., Bengal, XIV, 1845, Proceedings for February.

to Calcutta: it flickered several times as if the fire had been got under, and after lasting 15 or 20 minutes (say) suddenly went out. Various were the conjectures: I thought it was the reflection of the sun from below the horizon, but the sudden light of flame was too brilliant and unsteady to be the sun's light; electricity in the cloud was stated to be the cause, but this is not the season for such a cause: 'a ship on fire,' said many; but this morning the prevailing opinion is, that a volcanic eruption has taken place 20 miles out to sea, similar to what I reported as having taken place near Cheduba. The argument against its having been a ship on fire is, that the flame showing so brilliant and so great a light could not be so suddenly extinguished as this was, the dark bank of clouds may have been formed of the smoke of the volcano."

The light was also seen by Captain Siddons and others from Akyab, and from the H. C. schooner "*Spy*," then off the Assirghar shoal (about 30 miles north-west of Akyab), the Commander of which ship saw "five different times large masses of fires thrown up," which he supposed to be a volcanic eruption. It is scarcely open to doubt, however, that what was seen from the "*Spy*," at least, was the reflection of the fire from the bank of the clouds alluded to by Captain Williams, and not the flames themselves. The bearings taken from the above different places showed the position of the fire to have been about 7 miles S. $\frac{3}{4}$ E. from the south end of the Western Baránga, the distance from Kyauk Phyu being 31 nautical miles, from Akyab 28, and from the Assirghar shoal 57. As Kyauk Phyu and Akyab are both on alluvium, it is not probable that the observers in any case were more than 20 feet or so above the sea. Taking, therefore, the curvature of the earth (with refraction) into account, the flames to have been themselves visible at the above distances must, with reference to each position respectively, have exceeded 500, 400, and 2,000 feet in height!'

Soundings were made within a few days of the occurrence, but no difference from the soundings laid down on the chart was discovered.

An eruption, on a comparatively small scale, which took place from one of the Kyauk Phyu volcanoes on the 25th of October 1846, was thus described by Major Williams:—"About a quarter to 9 o'clock last night, we had an eruption of one of our volcanoes near the village of Chein Kroong,² about three or four miles from this station, on the island of Rámri; it burst out suddenly with a slight noise, emitting a brilliant flame, which instantly went out, and again burst forth; this happened for fifteen or twenty times, when the flame burnt steadily, gradually diminishing, and disappeared altogether about daybreak, or a little before it, this morning: it rained heavily all the time.

"The whole sky was illuminated brilliantly, and again suddenly everything was immersed in darkness during the flashes, and then sudden disappearance, which I can only compare to the effect, on a small scale, of a handful of oil, or any

¹ Humboldt mentions an eruption from a mud volcano near Baku, when the flames flashed up to an extraordinary height for three hours, and another in the same region during which the flames rose so high that they could be seen at a distance of 24 miles (Kosmos I). It is stated by Eichwald that the eruptions there always terminate with a pouring out of naphtha (Edin. New Phil. Journal, XIV, 132).

² Tsi Cháng?

combustible matter being thrown into a fire " ... " I have had a more correct description of the volcano to-day" : (28th) " The size of the crater is about six feet in diameter only, surrounded on all sides, to some extent, with soft mud knee-deep, and the jhow or cassuarino trees growing around unhurt, in a regular manner as if planted there; no other kind of trees near, and of course all other vegetation covered with the mud thrown out. It is still burning, and it is just now a place of resort by these superstitious people who make offerings to the Naga, the cause of earthquakes and volcanoes. It appears that there is no hole where the flame (still burning and about two feet high) issues from, it comes up through the soft mud."¹

According to some of the head men of Tsi Cháng whom I questioned, the time that has elapsed since the latest eruption from each of the different Kyauk Phyu volcanoes is roughly as follows :—

				Interval since last eruption.
1st	(most southerly) volcano	...	...	... 17 or 18 years.
2nd	"	...	...	... 10 years.
3rd	"	...	...	... Erupts almost yearly.
4th	"	...	...	... Extinct.
5th	"	...	...	... 3 or 4 years.
6th	"	...	...	... ?

The eruptions are only sometimes accompanied by flame. Four years ago there was a great eruption of the 3rd volcano: the heat given off by the flames was then so great that the villagers could not approach near, but looked on from behind the shelter of the neighbouring jungle.

There is a story well known over Cheduba and which was told to me, amongst others, by the Burman Extra Assistant Commissioner and by the head man of Kantháo Roa: although largely mixed up with fable, there would appear to be a substratum of fact, and it serves, at least, to illustrate the ideas held by the islanders themselves regarding their volcanoes. About three years ago, as it is said, a party of nine people from the village of Kaindi Roa, went to the Pagoda Hill to worship, one of the party being a man named Ngalaítké, which means a turtle in Arrakánese. On their return, and while passing over one of the large volcanic mounds near the Pagoda Hill, one of the men called out mockingly to the Nagá—a spirit in the form of a serpent that presides over each volcano—"O! Nagá Ji, here is a fine turtle I have brought; let me have some fire to cook him!" The offended Nagá granted his wish. Flames issued from the volcano. Four of the party were consumed and the remainder escaped more or less injured. The Extra Assistant Commissioner, while telling me the tale at Kantháo Roa, sent for a woman who was said to have been amongst the number, and who was marked with large scars like those produced by severe burns, which she said she had received on the occasion referred to. She had not, however, herself heard the insult offered to the Nagá. This part of the story will perhaps strike the sceptical as being open to some doubt, but that flames did issue suddenly and injure the people is, I am inclined to believe, a fact. It may be observed that in some of the preceding records, also, the eruptions are said to have had a sudden commencement.

¹ Journ. As. Soc., Bengal, Proceedings for November 1846.

There is a notion prevalent amongst the islanders that eruptions, from the volcanoes generally, take place more frequently during the rains than at other times of the year, an idea which can scarcely be considered as borne out by the few dates of eruption on record. Those mentioned above are respectively—

January	2nd.
February	6th.
March	23rd.
July	26th.
August	26th.
October	25th.

A greater tendency of eruption at certain times of the year has, however, been suspected to exist in some other parts of the world. It is stated by Dr. Horsfield that the eruptions from the mud volcanoes of Java are more violent during the rainy season than at other times,¹ and M. Dubois de Montpéreux mentions that out of six eruptions from the mud volcanoes near the entrance to the sea of Azov, five occurred between February and the 10th of May, the only known autumnal eruption having been on the 5th September.²

The vast majority of the ejected pieces of rock are from half an inch, or less, to 4 or 5 inches diameter. Stones of half a cubic foot are not very common, and those of a foot rare. Ejected stones. On the large mounds south-east of Pagoda Hill, however, there are a few blocks containing 3 or 4 cubic feet, or more, of rock. The height to which some of the stones have been thrown may be gathered from the distance from the mound to which they have been scattered over the surrounding phœnix ring.

The ejected stones are, without exception, fragments of the various kinds of rock found in the neighbourhood of the volcanoes, the great mass being shale and sandstone. These are often penetrated by veins of calcespar, and occasionally contain strings of lignite. Pieces of more or less impure limestone, also, are not uncommon. Bits of pyrites are occasionally found, but are far from plentiful.³

Very rarely indeed do the stones show any definite signs of alteration by heat. The only case I observed was that of some fragments of red shale, different in color from anything observed *in situ*. On exposing fragments of gray shale, however, from some of the oil wells, to a red heat over a Bunsen's burner, they became first dark colored and then red. Mr. Piddington mentions having received, amongst other specimens sent by Mr. Howe from the Kyauk Phyu volcano after the eruption of February 1843, a specimen which was "gray shale at one end and brick-red clay slate at the other, with the dark half-calcined-shale in the middle."⁴ Captain Halsted alludes to "a white stone, like chalk, found on all the large volcanoes, which was considered as the common greenish sandstone discolored by heat." The bleached-looking appearance of this rock, however, is deceptive.

¹ Daubeny on volcanoes, p. 409.

² Geological Observer, p. 475. Also Verneuil: Mémoires de la Société Géologique de France, III, p. 4.

³ Spoken of as "copper ore" by Captain Halsted, who also mentions "silver ore." The latter was conjectured by Mr. Piddington to have been marcasite, but no specimens were forthcoming for examination. (Journ. As. Soc., Bengal, X, 443, 449).

⁴ Journ. As. Soc., Bengal, XII, 336.

It is merely a fine-grained, slightly calcareous, white sandstone, which I have observed more than once *in situ* near the volcanoes.

Mr. Howe alludes to "masses and particles of lava" thrown up from one of the Kyauk Phyu volcanoes during the above mentioned eruption. Lieutenant Foley, also, says that at one of the craters in the same neighbourhood "scoriaceous matter, trap minerals, and basalt show evidence of more active volcanic agency in times past."¹ This statement is, however, completely erroneous. I have visited every one of the Kyauk Phyu volcanoes, and (knowing beforehand what had been written) failed to find a single particle of basalt, lava, scorïæ, or any other rock showing even a trace of fusion. The 'hard and sonorous rock resembling clinkstone, of a sea-green color and intersected with veins of calcspar,' found by Lieutenant Foley at the foot of one of the Rámri volcanoes, and conjectured by him to have been ejected in a state of fusion, was most probably a hard, fine-grained, greenish sandstone with calcspar veins through it. A rock of this kind may be seen, amongst other localities, on Flat Island. In another place, indeed, Lieutenant Foley says that "a few blocks of sandstone, and a conglomerate, consisting of a paste of sandstone, with enclosed nodules of a calcareous earth, lay upon the beach; some of these rocks had a scoriaceous appearance, were encrusted with crystals of iron pyrites, and bore evident marks of igneous origin."²

The inflammable gas which is evolved from the volcanoes, in bubbles during ordinary times, and in enormous quantities during the most violent eruptions, is evidently, in the main, marsh-gas, mixed probably with a varying proportion of other gases. During great eruptions it is not improbably mixed with the vapor of the more highly volatile of the petroleum hydrocarbons, as well as, perhaps, with the heavier hydrocarbons blown out in a state of spray. That a certain amount of heat is connected with such eruptions is evidenced by the hot or warm condition of the mud,³ but the unaltered state of the ejecta, especially such substances as lignite and pyrites which would undergo decomposition if strongly heated, show that the temperature is not very high. It is, I think, improbable that the gas issues during eruptions at a sufficiently high temperature to ignite spontaneously. The cause of its ignition may, perhaps, be inferred from the phenomenon frequently observed during eruptions of fragmentary ejecta from volcanoes in the usual sense of the term, like Vesuvius. During such times "forked lightnings of great vividness and beauty" are continually darted from the ascending column of stones, scorïæ, dust and more or less condensed vapor, the electricity being developed by the friction of the ejecta amongst themselves.⁴ The principle of the hydro-electric machine is very similar, in which large quantities of electricity of high intensity are produced by the issue of partially condensed steam through small orifices of such form as to create considerable friction. From a large machine of this kind a battery has been charged in half a minute which gave sparks 22 inches long.⁵ In the case of the mud volcanoes, when

¹ Journ. As. Soc., Bengal, II, 597.

² Journ. As. Soc., Bengal, IV, 23.

³ p. 196.

⁴ Scrope's volcanoes, pp. 22, 57.

⁵ Watts' Dictionary of Chemistry, II, 408.

quantities of stones, and of mud, doubtless reduced to spray by the violence of the action, are being shot into the air, the friction of the ejecta amongst themselves, must necessarily produce large quantities of electricity, and it is, I believe, to the sparks, or lightning on a small scale, thus produced, that the ignition of the gas is due. The flames at the surface are sufficient to account for the calcination of the fragments of shale mentioned above.

It will be observed that the fire of the mud volcanoes differs from that so often popularly spoken of in connection with lava-emitting volcanoes, in that the former is due to real flames, the latter being the reflection of the light from glowing lava by masses of condensed vapor, or of dust and scorïæ, or, in other cases, the light from jets of incandescent lava-drops.

In the mound south of Kyauk-galé we have an instance of a mud volcano in an almost extinct, or, at any rate, long dormant condition. Instead of the usual heap of bare stony-looking debris, the mound is clayey at the surface and covered thinly with grass, with a few scattered casuarinas around. When I saw it there was one small mud cone at the centre from which bubbles of gas were being given off, but the amount of mud recently ejected,—*i. e.*, covering, instead of covered by, grass,—did not exceed a few cubic feet. The mound, about 100 yards in diameter and perhaps 15 feet high, is situated on a raised beach, whose present elevation of about 20 feet above the sea only dates back to the middle of the 16th or 17th century.¹ Previous to that time there may of course have been submarine eruptions, but if so, the loose ejecta must have been carried away by the sea. The present mound can never have been exposed to the surf, and as it is now very nearly extinct, the maximum length of its period of subaërial activity can be inferred.

The third of the Kyauk Phyu volcanoes, counting from the sea, is in a still more advanced stage. It is a cone of low gradient, with a depression a few yards in diameter at the summit, containing a pool of water bordered by rushes—a miniature crater lake. The cone is thinly overgrown with grass, and casuarinas are dotted over it accompanied by other trees. After eruptions have ceased, the salt is gradually washed out of the debris by rain; slowly probably on account of the impervious character of the mud. The cone thus by degrees becomes less fit for the growth of casuarinas, and more suited to that of ordinary jungle, which ultimately doubtless usurps the place of the former trees completely.

I have already alluded to the position of the Arrakán salses at or near the end of the great Sunda group of volcanic vents. The next to them are Narkondám and Barren Island, both of which are volcanoes in the ordinary sense of the term.

There is of course a wide gulf between the two classes of volcanic phenomena. Indeed some authorities, like Dr. Daubeny and Mr. Scrope, do not regard salses as truly volcanic at all, grouping them as pseudo-volcanic phenomena.

For the production of any volcanic cone three main conditions are necessary : 1st, the reduction of rock at a greater or less depth beneath the surface to a mobile condition ; 2nd, a practicable vent by which such rock can be forced to

¹ p. 190.

the surface; and 3rd, the presence of a power competent to force it up to the mouth of the vent and leave it there to reconsolidate. In the case of 'true' volcanoes the mobility is *in the main* gained by the reduction of rock to a state of fusion, the heat involved in the process being due, as has been shown by Mr. R. Mallet, to local crushing of the earth's crust, caused by the secular refrigeration of the globe, the interior cooling, and consequently contracting, faster than the exterior, which is thus subjected to tangential thrusts. The force by which the lava is ejected is the pressure of steam raised to a high temperature by heat derived from the same source as that which fuses the rock.¹

In the case of salses the mobility is produced by reduction of rock to a state of mud, either by partly chemical, or by purely mechanical means.² The ejecting force is sometimes the pressure of steam; in other cases, including the Arrakán salses, it is, mainly at least, that of gaseous hydrocarbons.

Amongst the most prominent examples of steam mud volcanoes are those in New Zealand, described by Dr. Hochstetter, where are craters filled with boiling mud from which steam escapes explosively at intervals, accompanied by sulphuric acid and other gases, to whose action on the lavas underground Dr. Hochstetter attributes the origin of the mud.³ Of a similar character are the boiling mud volcanoes of Iceland, which have been described by Professor Paijull, Captain C. S. Forbes, and others. Such also are the mud volcanoes of the Colorado desert. From some of these "the steam rushes in a continuous stream, with a roaring or whizzing sound, as the orifices vary in diameter or the jets differ in velocity. In others the action is intermittent, and each recurring rush of steam is accompanied by a discharge of a shower of hot mud, masses of which are thrown sometimes to the height of a hundred feet."⁴

In all the above cases the mud cones are in the closest relationship with existing, or but recently extinct, phenomena of volcanic fusion; the mud is produced by chemical action of acid gases on volcanic rocks, and the steam is generated by the heat which originally fused these, or by heat which has been produced in the same way. The heat required, however, is of a much lower degree of intensity, and hence such steam mud volcanoes may long outlive the immeasurably grander phenomena of the lava-emitting period. It is of course necessary that the springs should be *boiling*, steam at considerable pressure, but whose force is dissipated at the vent, being the power involved. A spring of water merely, whether hot or cold, bearing a certain proportion of mud to the surface, would be equally capable of carrying it away from the mouth of the vent, so that although a deposit might be formed, it could not be in the form of a crater-bearing cone.

The volcanoes of Rámri belong to a different class. There the mud is not produced by chemical means, but by mere mixture of shale and clay with water. The ejecting force is evidently the pressure of gas, which is in large part, at least,

¹ Phil. Trans., 1873.

² In both fusion and mud volcanoes mobility is conferred on a certain proportion of rock by mere breaking up sufficiently small to admit of ejection along with the fluid materials.

³ 'New Zealand,' pp. 401, 432.

⁴ Silliman's Journal, XXVI, 292.

light carburetted hydrogen, mixed perhaps with the vapor of the most volatile liquid petroleum hydrocarbons.¹ Bubbles of this gas are given off from the mud cones in their ordinary state, as well as from most of the petroleum wells. There are two of the latter at Létaung, about 25 and 40 feet deep, from which the issue of gas is so considerable that it can be heard bubbling up when standing some yards away from the mouth. I roughly guessed the amount at a cubic foot every few seconds, and the villagers say that the well has been in its present state, without diminution of either oil or gas, for many years. Here the gas is being continuously and quietly evolved. The quantities that (having probably gradually accumulated in fissures during long periods) are suddenly liberated during violent eruptions of the volcanoes, may be inferred from the foregoing records.

Recollecting the great tension at which quantities of gas are often stored up in coal mines, and the force with which it escapes from the 'blowers' there, as well as from many bore-holes in the oil regions of America and elsewhere, it is not difficult to conceive that in some cases gas mud volcanoes may be caused, where the other necessary conditions are present, by the pressure of gas due merely to its continued slow generation from carbonaceous matter at the normal temperature of the strata at moderate depths. But given certain coal- or lignite-bearing rocks, producing oil and gas; if they are situated on a line of volcanic heat (although of low intensity, insufficient to fuse, or materially alter, the rocks accompany such carbonaceous matter), the tension of the gas and vapor may, doubtless, be greatly increased by the larger proportion of gas, compared to that of oil, produced at the higher temperature, and by the increased tension due to a higher temperature, where gas is stored up in a fissure of given capacity. In this connection the difference between the petroleum of the Irrawádi valley and of Rámri may be noticed. The mud volcanoes of the former region have been described by Dr. Oldham as very sluggish, and as never exhibiting the fiery paroxysms to which those in Rámri are subject. At the same time the oil is dark colored, is as thick as treacle, or even solid, at 60° F., being indeed often spoken of as 'Rangoon tar,' and contains paraffine to the extent sometimes of more than 10 per cent. The Rámri oils are associated with much gas, and are themselves sometimes as transparent and light colored as brandy. They have a lower specific gravity than the above, and at 60° are perfectly mobile. Without venturing to assert that the above differences are due to a difference in the temperature at which the oils have been produced,² it may be noticed that at Baku on the Caspian, where there are mud volcanoes

¹ Whether the temperature of the emitted gases from the Rámri salses is ever sufficiently high to allow of steam playing any important part is a question as yet undetermined. Amongst other mud volcanoes which are intimately connected with petroleum may be mentioned those of Java; those near the eastern shore of the Caspian; at Baku; and near the entrance to the sea of Azov; those near Girgenti in Sicily; and along the northern flanks of the Apennines by Modena and Parma, and those in the Island of Trinidad.

² The occurrence of fragments of unaltered lignite amongst the ejecta from the Rámri volcanoes, although one amongst many indications that the subterranean temperature is far below that beneath fusion volcanoes, does not necessarily prove that the temperature may not be considerably above the normal one for the depth, as such fragments may have been torn from the upper part of the vent.

subject to fiery eruptions, similar to those of Rámri, the oil is in part of the same pale transparent kind, and is accompanied by immense quantities of gas. Abich found the temperature of the soil there to be 59° F., of the naphtha 62.5° to 66° , and of the gas-springs 68.5° , and Bischof considered that "the low temperatures above given of the exhalations of Abscheron, where volcanic action in the depths might be conjectured, exclude the notion that heat has any share in their formation."¹ Eichwald, however, arrived at a different conclusion. "Near to Baku," he wrote, "about one-fourth werst from the perpetual fire, a heat rises out of a fissure of the shell-limestone, which is so strong that the hand can scarcely bear it: hence, from all these circumstances, we can scarcely doubt of the existence of a subterranean heating process in the peninsula of Abscheron."² Sir R. Murchison, also, has expressed the opinion that the mud volcanoes of the Caucasus "have a deep seat, and are as directly connected with internal igneous agency as any other geological phenomena of eruption."³

The evidence is clear as to the intimate connection of the Rámri salses with seismic phenomena at least. Out of the few eruptions of which accounts have been printed, three certainly, and probably four, were synchronous with earthquakes. During the principal shock of the violent earthquake on the 26th August 1833, it is stated by Dr. McClelland that flames issued to a height of several hundred feet from one of the Kyouk Phyu salses. A similar occurrence took place during the earthquake of the 23rd March 1839. The submarine outburst near False Island of the 26th July 1843 was immediately preceded by a like disturbance. Further, during the great earthquake of 2nd April 1762, two volcanoes are said to have opened in the Chittagong District. If these really were volcanoes, and there seems no reason to question it, they were doubtless of the same class as those in Rámri. The connection in some cases may lie in the shock sufficiently loosening the superincumbent rock to allow the pent-up gas to force a passage: in others, it may perhaps be due to a diminution in the size of the fissure, either momentarily during the passage of the wave, or permanently from a partial falling in of the sides. In either case a sufficiently increased tension of gas might be produced to bring on an eruption. It is noticeable that during the earthquake in the last century, when the islands were elevated several feet, no eruptions are recorded, and it is specially mentioned that none took place in Cheduba. In the Chittagong District, during what was probably the same earthquake, the ground was depressed, and two new volcanoes are said to have broken forth.

Besides the mud volcanoes in the various localities along the flanks of the Arrakán Range, mentioned at page 193, the only phenomenon of the kind in Eastern India that I am aware of occurs in Upper Assam. It is thus described by Captain Hannay:—"At Namtchuk Pathár, near the mouth of the river, the petroleum exudes from the banks, and a bed of very fine coking coal runs across the bed of the Namtchuk. The hills here are also intersected by ravines, and in

¹ Chemical Geology, I, 252, 257.

² Edin. New Phil. Journal, XIV, 132.

³ Russia and the Ural Mountains, p. 576.

one spot an extensive basin or hollow is formed at some height, which contains muddy pools in a constant state of activity, throwing out, with more or less force, white mud mixed with petroleum. This is indeed a strange looking place, and I am told by the Singphos that at times there is an internal noise as of distant thunder, when it bursts forth suddenly, with a loud report, and then for a time subsides.¹"

On the borders of Western India, in the Beluchistáni District of Lus (north-west of Karáchi), numerous mud volcanoes are scattered over a large area. They have been described by Captain Hart,² and subsequently by Captain Robertson³. A copy of one of the latter officer's sketches may be found in Lyell's *Principles of Geology*. Although some of the cones there would appear to be on a larger scale than those in the Rámri group of islands, no mention is made of violent eruptions, either with or without flames,⁴ nor of ejected stones. In one case, indeed, Captain Hart specially mentions that the entire cone is of mud, without stones. If eruptions at all resembling those of the Rámri salses had taken place within the memory of the then existing generation, the above observers could scarcely have failed to hear of them. It would seem as if the cones have been raised by emissions of mud, insignificant individually, but continued during lengthy periods, or else that the period of violent eruptions is over, and that the stony ejecta have been covered by the later more tranquil emissions of mud alone.

ON THE MINERAL RESOURCES OF RÁMRI, CHEDUBA, AND THE ADJACENT ISLANDS,
by F. R. MALLET, F.G.S., *Geological Survey of India*.

In 1877 the existence of coal in the southern part of Rámri was brought to the notice of Colonel Sladen, Commissioner of Coal. Arrakán, by Mr. W. Savage, who had examined the coal-bearing locality, and who forwarded a short memorandum on the subject. In this he described the excavations he had made at Tsetamá, and pointed out the favourable position of the coal with regard to water carriage. The Hon creek, Mr. Savage remarked, is navigable for boats of 6 or 8 tons to within a quarter of a mile of the coal, while the mouth of the same creek is open to vessels of 500 tons. Specimens of the coal, sent to the Geological Museum, proved on assay to be of passable composition. Subsequently I was directed to visit the islands and examine this locality, as well as any others in which indications of coal had been observed.

Previously to my visit, Mr. Duke, the Deputy Commissioner, had issued instructions to the Tehsildárs to send information, accompanied by specimens, of any coal-like substances known to occur in their respective townships. Altogether

¹ Journ. As. Soc., Bengal, XIV, 819.

² Trans. Bombay Geograph. Soc., II, 87.

³ Journal Bombay As. Soc., III, 8 (January 1850).

⁴ Captain Robertson mentions that a lighted stick held over an aperture from which bubbles of gas were escaping produced no effect. It would be somewhat rash, however, on the strength of this solitary and somewhat rough experiment, to assume that the gas generally is non-inflammable.

specimens were received from eight different places, all of which I went to. The coal at five of them, however (*viz.*, Pharungjuan Island, about 10 miles north-east of Kyauk Phyu, Then Chaung, Kángautau, Thitpoktaung and Sengu), turned out to consist merely of lenticular nests of lignite, or of stems, partly carbonized and partly silicified, such as have been described in the foregoing paper (p. 191). As sources of fuel they are of course perfectly useless, and do not need any further remark. The coal at Tsetamá, and near Pallang Roa in Cheduba was found to occur in true beds. As I have already briefly sketched the geological character of the Rámri strata, I may here proceed at once to describe the coal itself.

The locality where the best seams, hitherto found, outcrop is rather less than a mile west-10°-north of Tsetamá village. In the bed of a small nulla, at a spot some 30 feet above the foot of a range of hills, which are a few hundred feet high, and composed of sandstone and shale, the following section (given in descending order), was exposed by digging:—

	Ft.	In.
Gray shale, seen	3	0
Coal, with two or three thin partings of carbonaceous shale	6	0
Brown shale, seen	1	6
Dip south-20°-west, at about 50°.		

Fifteen yards lower down the nulla there is another outcrop, of which the section is as follows:—

	Ft.	In.
Shaly sandstone, seen	3	0
Shaly coal	0	8
Carbonaceous shale	0	1
Coal	0	4
Carbonaceous shale	0	3
Coal	1	1
Gray shale, seen	2	0
<hr/>		
Coal in seam	2	1
Carbonaceous shale	0	4
<hr/>		
Thickness of seam	2	5
Dip west, at 50°.		

The coal in both seams is somewhat shaly looking as a whole, although some layers are much better than others. It is strongly laminated; and this, combined with jointing, causes most of it to break up small. The greater portion cannot be extracted in lumps. Some improvement in this respect might, however, be hoped for at a greater depth, with respect to freshly raised coal, but such coal would probably not admit of storage for any length of time without deterioration. The above outcrops remind one much of those of the inferior coal seams in Upper Assam, which there is some reason to believe are of the same age. I have shown in another report¹ that some of the coal there when freshly raised from a moderate depth is hard and firm, but falls to pieces after being exposed for a time. The specimens sent by Mr. Savage underwent a similar deterioration

¹ Mem. G. S. I., XII, 346.

within two or three months, due mainly to the production of minute crystals of copperas from oxidation of the pyrites in the coal.

Several pits were sunk by Mr. Duke's orders on the hill side a little above the nulla. Coal was obtained in some of these; it, however, probably belongs to the same seams. The strike is very irregular.

A little below the 2' 5" seam there is one of very fair coal; but it is only about a foot thick.

On a low hill north-east of Tsetamá, or about a mile and a half east-north-east from the last locality, the following section was exposed:—

	Ft.	In.
Brownish shale, seen	2	0
Carbonaceous shale	0	7
Brownish gray shale	0	1
Carbonaceous shale with some coal	0	7
Grayish shale, seen	1	6
Dip south-30°-west, at 80°.		

Near to this there is a spot where fragments of coal are strewn about, and from which, the villagers with me said, Major Williams had dug some coal about 30 years ago. His excavation is, however, now filled up, and after several attempts I failed to unearth the outcrop.

In a small stream descending the hill north-east of Pallang Roa, in the southern part of Cheduba, three spots were pointed out to me about 30 yards apart. In one of these was a bed of coal 2' 6" thick, with brownish gray shale above and below it, dipping east-20°-south at 40°. It is similar in appearance to the brittle coal at Tsetamá. In the second spot there was merely a few inches of carbonaceous shale, and in the third two or three feet of a more recent sandstone containing angular fragments of coal similar to that in the 2' 6" seam.

Discoveries of coal have also been reported from more than one locality elsewhere. Thus Captain Halsted in 1841 described a seam which occurs less than a mile from the beach to the south of Pagoda Hill. It dipped at a high angle and was three and a half feet thick, but appears to have been carbonaceous sandstone rather than coal. Captain Halsted "could not make it ignite, it only smouldered."¹

Coal was also reported from near Kyauk Phyu in 1833, and some excavations made to expose the outcrops. One seam is described as being nearly vertical, from six inches to a foot in thickness, and as containing much pyrites. Coal was found in one or two other places also in small quantity, but the descriptions given lead one to suspect that it was nothing more than carbonized stems.²

A spot was pointed out to me at the north-west corner of Tengkreh Island (about 10 miles north-east of Kyauk Phyu), from which some black stuff had been brought. It had been dug from an irregular bed, three to six feet thick, of

¹ Journ. As. Soc., Bengal, X, 444.

² Journ. As. Soc., Bengal, II, 595; X, 144.

carbonaceous sandstone, containing perhaps 15 per cent. of combustible matter. As fuel, it was of course quite useless.

It will be seen, then, that the indications at Tsetamá are much more promising than those anywhere else, and it remains for me to give my opinion as to the prospect of successfully working the coal there.

I have already pointed out that, like that of Upper Assám, it may be divided into hard and soft coal. The former is unweathered at the outcrop and can be extracted in large pieces. But only one bed, a foot thick, has been discovered of this kind. The soft coal is broken and crumbly at the surface, but may improve at some depth. Such coal, however, would not be likely to admit of storage for any length of time without deterioration.

The following assays have been made to determine the composition :—

Seam.	Fixed carbon.	Volatile matter (exclusive of water).	Hygroscopic water.	Ash.	Caking properties.	Color of ash.
Tsetamá (sent by Mr. Savage).	43·5	28·8	8·4	19·3	Cakes very slightly.	Reddish gray.
6 feet seam, Tsetamá .	38·4	28·9	14·6	18·1	Does not cake.	Light gray.
1 foot seam, Tsetamá .	48·6	33·1	10·8	7·5	Cakes.	Red.
North-east of Pallang Roa	36·1	28·7	16·2	19·0	Does not cake.	Pale red.

The average composition of Rániganj coal, deduced from the assay of 31 samples, and of coal from the Sántoria seam, which may be taken as a fair example of the best class of Rániganj coal, such as is supplied to sea-going steamers, is as follows¹ :—

	Fixed carbon.	Volatile matter (exclusive of water.)	Hygroscopic water.	Ash.
Average	53·20	25·83	4·80	16·17
Sántoria	61·40	23·20	2·20	13·20

It will thus be seen that the Rámri coal is decidedly inferior to the Rániganj, and experience of nummulitic coal elsewhere shows that no marked improvement in composition can be hoped for at a greater depth from the surface.

The quantity of coal to be expected depends mainly on the thickness of the seams, their continuity and number. There is at least one known of sufficient thickness for convenient mining. With regard to their continuity, it would be hazardous to express any definite opinion. No natural sections are available by which any of the seams can be traced along the strike, and the attempt to do so by excavation would be a work involving a far greater expenditure of time and money than my instructions would have warranted. Disappointment has before now been experienced in Pegu in attempting to work similar coal, which on the original outcrop seemed to hold out good prospects of success, but which was

¹ *Rec. G. S. I.*, vol. X, 156.

found on trial to die out rapidly.¹ On the other hand, the seams of nummulitic coal in Upper Assám have been traced in several cases for long distances. As for the number of the Rámri seams, there is of course a possibility of other beds being discovered, better perhaps than any at present known, but the natives of the locality, intimately acquainted with their jungles, say they possess no knowledge of any others than those described above. To search for outcrops at random in a country where the rocks are so obscurely seen, and without a map,² would be mere waste of time. But I think it may be predicted with some confidence that coal will not be found in anything like *abundance*. Where rocks are tilted up on edge, like those in question, any seams included in them must necessarily be cut through by streams running across the strike, and, in such cases, if the coal exists in any quantity, ample indications of its presence are generally afforded by the fragments, and often large lumps, washed down. But nothing of the kind is to be found amongst the shingle of the main streams near Tsetamá, which drain many square miles of country.

With reference to the extraction of the coal, the high inclinations of the seams would preclude quarrying on any but the most insignificant scale. The coal could only be raised in any quantity by mining, and mining in seams with such high and irregular dips would not be of the simplest kind.

Altogether, then, the prospect of successfully working the coal is not promising. Assuming, even, that the quantity is sufficient, the difficulty of mining it would necessitate a skilled European manager on a good salary, and to cover that expense a considerable quantity of coal must be raised. But the local demand is trifling, and beyond the sea, the mediocre quality of the coal and the expense of mining it, would, I am of opinion, prohibit its competing on even terms with the easily-mined and superior coal from Rániganj. Sea-going steamers, with Bengal and English coal at command, would certainly not take such coal as that which has hitherto been found in Rámri, and I do not think it could be raised at such a price as to find a market even for local purposes at Akyáb.

In the preceding paper I have alluded to the connection between the mud
Petroleum. volcanoes and petroleum, and to the difference be-
 tween the oils of Rámri and those of the Irrawádi
valley. In as far as one can form any definite idea from mere description, the oil-bearing rocks in both regions would appear to bear considerable resemblance to each other,³ and it has been stated by Mr. W. Theobald that they are certainly of the same geological age.⁴ I think it can scarcely be doubted that the lignitiferous beds of Rámri and Cheduba are the true oil-producing as well as oil-bearing rocks.

In the Baránga Islands, however, although the oil is of the same character as that from Rámri, a marked difference is apparent in the rocks from which it issues. These are shales and sandstones of very constant character, without

¹ Selections from the Records of the Government of India (Home Department), No. X, p. 99.

² The revenue map does not even profess to mark the hills or streams.

³ Mission to the Court of Ava, p. 312.

⁴ Mem. G. S. I., X, 163.

the irregular calcareous nodules and nodular masses which are so generally characteristic of the beds in Rámri. I have never observed any appearance of either calcareous or carbonaceous matter amongst them. The shales are gray, brittle, sometimes slightly unctuous, often more or less arenaceous; they are frequently somewhat clunchy. The sandstone is generally gray or greenish-gray and tolerably fine grained, and is interbanded with the shale. The strike of the rocks is extremely regular, often running in a straight line for miles, and indeed varying little from end to end of the islands. The strata are thrown up at high inclinations, generally dipping at angles between 60 and 90 degrees. I am inclined to believe that the calcareous and lignitiferous rocks are rolled up with the above, and that it is from the former that the oil is originally derived in the Barángas as well as in Rámri. It is true that they do not appear in any part of the Barángas that I have visited, but my acquaintance with the islands is very limited,¹ and it is not impossible that, owing to less capability of withstanding denudation, they occupy the submarine areas between the islands. The similarity of the rocks in the three Barángas, and the observed dips, lend some little support to the idea that the Phadu and Chengdamma channels may mark the position of anticlinal bends with a synclinal between in the position of the middle island.

The digging of oil wells appears to have been carried on by the inhabitants of Rámri and Cheduba for a long time past, and at the present time such wells are worked in numerous localities. None of them, however, have been sunk to any great depth, and the scale on which the industry is conducted is comparatively trifling. It does not appear to be in the hands of any special class. About the end of December, or early in January, when the rice crop has been harvested, and the villagers have spare time on their hands, some of them take to well-digging as a means of adding to their income. The oil season lasts from that time till the rains, when the wells, which are most frequently sunk in, or close to, the bed of some nulla, get filled with water, and are often choked up entirely by debris washed into them.

The wells are of two classes—those which appear to be in communication with a natural reservoir, from which the oil, generally accompanied by large quantities of gas, rises with considerable rapidity, and those sunk in rock more or less soaked with petroleum from which the oil slowly exfiltrates into the well. The latter case imitates on a small scale the process which has been going on for ages on a large one in the case of the natural subterranean fissures.

To the former class would appear to belong the wells at Létaung near the western coast of Rámri. One of these is about 25 feet deep and 4 feet square. It is lined with wood throughout, so that the rock cannot be seen. At the bottom is water covered by a stratum of oil, through which a rather large quantity of gas bubbles up, chiefly from one corner of the well. The oil is drawn morning and evening, and the yield is said to be 15 bottles each time: much reliance, however, cannot be placed on figures supplied by the owners or lessees of the wells. Another well of the same kind, about 200 yards north-

¹ It is said that lignite has been found on the Eastern Baránga, but the exact locality is unknown.

west of the above, is about 40 feet deep, with water and oil at the bottom, which seems to boil gently from the issue of gas. The yield is said to be about 25 bottles twice a day. I was told that these wells have been in existence since the time of the Burmese domination, and that the yield of oil has not diminished. I am unable to say whether this statement is correct. The yield of oil, however, is only a few gallons a day, a quantity that a large reservoir, tapped only by a small duct leading to the bottom of the well, might supply for a very long period. The locality is worth notice. Close to the north-westerly of the above wells a new one was being sunk, in which the rock below the surface soil was a gray clay with a tendency of a peculiar kind of irregular flakiness. The strike cannot be seen, but to the north-east of the wells there is a ridge (doubtless as usual parallel to the strike of the beds composing it) running north-west—south-east, or parallel to the direction the wells bear to each other. It is noticeable that the clay from some wells that were being sunk last December at the village of Tsi Cháng (near Kyauk Phyu) was of a character similar to that at the Létaung wells, and that the oil was of a similar kind also, both in color (a pale yellow) and in specific gravity.

The not unfrequent fiery eruptions from one or other of the mud volcanoes occurring in a line near Tsi Cháng leave but little room for doubt that there is a fissure beneath them, in which large quantities of gas are generally stored up, and it is at least highly probable that a considerable quantity of oil is associated with the gas. A lucky boring might strike a spouting reservoir of great capacity, but of course such an undertaking would be of a speculative kind. There are no data to determine at what depth the oil is stored, nor what the inclination of the fissure may be, whether vertical or at a greater or less angle. A boring therefore sunk actually along the line of vents might miss it altogether. A few holes, however, sunk in a line at right angles to the line of vents, could hardly fail to strike it if sunk sufficiently deep. The experiment would certainly be an interesting one whether rewarded with success or not.

Gas is stored beneath the other active volcanoes also, but the linear arrangement of the Kyauk Phyu vents gives a better clue to the direction of the fissure than is obtainable elsewhere.

The wells in the southern part of the eastern Baránga, from which Mr. Savage has recently obtained such encouraging results, are evidently of the class now alluded to. They are sunk in gray shale which splits with a rather smooth fracture having a slightly unctuous feel. The bedding is very nearly vertical. It appears from the official correspondence on the subject that "Mr. Savage dug two wells about 500 feet apart, and then commenced boring. On the 25th February he struck oil in one well at a depth of 66 feet; the oil at once rose in the well . . . to a height of four feet; it kept at this level for about seven days, and in that time yielded, Mr. Savage thinks, 1,000 gallons a day; since then the oil has remained in the bore-hole a few feet below the bottom of the well, and 120 gallons or more a day can be dipped out with a dipper. A great deal of the oil escaped from the well through fissures." "The well at its mouth was some 15 feet in diameter, and had been dug with those dimensions of a depth of some 30 feet. Here boring commenced, and had been

carried to a depth of 36 feet only, when the workmen were surprised and terrified by a sudden outburst of gas and oil, accompanied by loud subterranean sounds, as of distant thunder. They had only time to make their escape up the ladders of the well before the oil and gas poured in in quantities that would otherwise have made their position a very perilous one." "Four days after Mr. Savage struck oil in the second well at a depth of 68 feet under similar circumstances, but the gas appeared stronger, making a great noise. About 150 gallons a day can be dipped out of this well... The oil is clear and liquid; large quantities of gas continually escape not only in these wells, but in all other wells of small depth which are in the locality."

Of the second class of wells those near Minbain are amongst the most important. There are several scores of them, about a mile and a half north of the village, in an alluvial plain which is cut up by numerous nallas, which join and eventually drain into the Phultánu naddi. The wells are all sunk either in or close to the beds of the nallas, such being of course the lowest ground in the locality. They occur in groups of a dozen or twenty, the groups not being very far from each other (say one or two hundred yards), and the wells within a few feet or yards of each other. They are about 4 feet diameter, and vary in depth from 5 or 6 to 10 or 12 feet, and are all sunk in a rather tough grey clunch, which is generally covered by a foot or two of surface soil. In some wells the clunch towards the lower part is entirely soaked with petroleum, but more frequently the oil soaks the rock in patches, which have a darker color than the rock which is free from it. Although none of the wells are in communication with anything approaching the dignity of a fissure, there are evidently divisional planes and minute cracks which allow the oil to rise more freely in some spots than in others. At the bottom of the wells holes about 8 inches diameter and a foot deep are dug in the oleiferous patches of rock, in which the oil accumulates. It is collected twice a day; according to the sinkers, a good well will sometimes yield 4 or 5 bottles twice during the first day, but the yield rapidly diminishes. A few wells are failures, and yield no oil. One of the head men of Minbain, who was engaged in the well-digging, informed me that they are worked from about the beginning of December till the commencement of the wet season. The wells being mostly in the beds of nallas, of course get filled with rubbish every rains, but, as the yield diminishes so much with age, the diggers do not mind this, and open others in fresh spots every year. The annual yield is said to be about a thousand rupees worth of oil of late years. It is sold at six bottles per rupee. The total, therefore, would be 6,000 bottles or about 1,000 gallons.

In the ridge which stretches along the sea coast from Likman to Minbain, the strata have a dip throughout to south-west. The dip is very obscure in the ridge between the wells and Thengchaung, and it does not seem to be regular, but I observed some apparent indications of its having a general easterly tendency. If this be the case, the oil-bearing rocks near Minbain are probably at or near the axis of an anticlinal bend, a position which in many oil regions (some of those in America and Japan for instance) has been found a most favourable one for well-sinking. The present wells, as will have been seen, have merely grubbed at the surface.

A mile or so north-west of Kangautau, there are a dozen or so of oil wells in the bed of a nalla of the same character as those at Minbain. They are sunk in a gray, more or less argillaceous sand (disintegrated sandstone?), some being lined with bamboo wickerwork. They were first opened last year. The best well, as I was told, yielded eight or ten bottles of oil the first day, but the yield rapidly diminished.¹

The following table contains as complete a list as I have been able to make of the localities in the Rámri group of Islands and the Barángas, where oil has been obtained or indications of it observed. With reference to the Barángas it should be remarked that the results given are, with the exception of those connected with Mr. Savage's wells, those obtained up to the time of my visit. Boring operations had, however, then only just commenced, so that the small quantities of oil mentioned cannot in themselves be taken as any evidence of a scanty supply.

¹ Captain Halsted states that in Cheduba oil is collected by turning up the soil, where oleiferous, to a depth of 2 feet, and surrounding it by a bank of earth, so as to form a shallow pond during the rains, about 20 yards square; gas and oil rise through the water, the latter of which is skimmed off and collected. (J. A. S., B., X, 369). This crude method was not practised in any of the oil-bearing localities I visited.

Locality.	Character of wells.	Rock in which wells are sunk.	Number of wells.	Depth in feet.	Stated daily yield in bottles. ¹	Color of oil by transmitted light. ²	Specific gravity of oil at 62° F.
<i>Rámrí.</i>							
Ts'i Cháng	Three wells were being sunk in December. Two were only a few feet deep: the third was 20 feet, and had struck oil in small quantity.	Gray clay with sandy and earthy calcareous nodules.	3	20	¹ 2	Transparent; color of brandy.	·809
Likmau	Well full of water in December; the rice crop was being harvested and oil collecting had not commenced. Indications of petroleum occur in three other spots near the village. One of these is on the beach, where a shallow well has been sunk which has yielded a little oil.	Sandstone?	2	About 18	3		
Minbain	See above	Gray clunch	Several score	5 to 12	0 to 8 or 10	Opaque; reddish brown in thin layers.	·867
Kángautau	See above	Gray argillaceous sand (disintegrated sandstone?)	12—15	5 to 12	0 to 8 or 10	Transparent; color of sherry.	·839
K'yangk Galé	Several pits about 100 yards from the shore on raised beach; they are from a few feet to as many yards diameter and one to two yards deep. Early in January they were filled to within two feet of the top with water, through which gas rose in some of the pits, and there was a faint smell of petroleum. According to the Tehsildár of Konboing, when these pits are emptied of water and dug out to some 15 cubits, they yield some oil. During the rains they get filled up with mud, &c.	Gray clunchy shales.	5 or 6	3 to 6	¹ 2, 1 and 4		

Létang	See above	Gray clay	2 ?	...	...	Transparent; pale yellow.	812
Cheduba.	No. 1 . . . . .	...	...	...	About 25 to surface of oil.	About 80	...
	No. 2 . . . . .	...	...	...	About 40 to ditto.	50	...
	Wells said to have been first opened about four years ago; they are sunk near the bed of a nalla.	Superficial deposit of clay with rounded stones; the rock beneath is probably gray shale.	6-8. At times, it is said, there have been as many as 80.	10 and less	1 on an average.		
1½ mile west of Cheduba Town.	Mentioned by Captain Halsted (J. A. S., B., X., 369, 446). It had been destroyed by fire previous to 1841, but the soil around it was "full of the oil."	...	...	...	0 (1841)		
5½ miles north of Pagoda Hill.	Two wells not far from each other (Captain Halsted.)	...	2	...	60 pots each annually (1841).		
Near north point of Island.	Some shallow wells on sea bench.						
North-west of Kama.							
3 miles south-east of Pagoda Hill. At Kaindi Roa.	Mentioned by Captain Halsted. One of these is said to have yielded nearly 200 pots of oil annually, but it is not clear which is alluded to.	...	...	...	Nearly 200 pots annually (1841).		
Round Island.	There is a spot near the centre of the hilly ground on Round Island, where a smell of petroleum is perceptible in hot weather.						

These figures, in as far as the Rāmri group of islands are concerned, are not very reliable. * In cylindrical bottles of 2½ inches internal diameter. All the oils are dichroic.

Locality.	Character of wells.	Rock in which wells are sunk.	Number of wells.	Depth in feet.	Stated daily yield in bottles.	Color of oil by transmitted light.	Specific gravity of oil at 62° F.
<i>Flat Island.</i>							
Less than $\frac{1}{2}$ mile south-east of volcanoes.	Several pits nearly filled with water in January; gas rises rather copiously from some of them, accompanied by oil.	...	About 6	3 or 4	About 1		
About 1 mile south-south-east of volcanoes.	Pits similar to the above . . .	...	2 or 3	3 or 4	About 1		
<i>Baránga Islands.</i>							
East Baránga: west of Klamang-doch H. S.	Boring (in progress) on spot where an issue of gas had been observed.	Gray micaceous arenaceous shale.	1	70	0		
Upper part of Ahongjukhi naddi.	Pit in the bed of the nalla. A bottle or two only of oil was obtained, and the pit then abandoned. It is now filled with water, covered by a slight scum of oil; the rock in spots on the brink is impregnated with petroleum.	Gray rather fine-grained sandstone.	1	9			
A little south of Raung naddi.	Mr. Savage's wells and borings mentioned above	Gray shale . . .	3	...	...	Transparent; red.	.835
No. 1 . . .		...	...	66	1,000 gallons a day during first week. Later on 120 gallons a day.		
No. 2 . . .		...	...	68	150 gallons a day.		

	No. 3.—A well opened previously to the above, which has fallen in, and is now abandoned.	...	12 or more	10 or 12	About $\frac{1}{2}$ man every 3 or 4 days.	
On sea-beach between Raung and Pukhach naddis.	Several shallow pits, which at spring tide are filled with water, through which gas with a little oil rises. At neap tides small quantities of oil are obtained from them.	Grey arenaceous micaceous shale.	12 or more	3 to 6		
North bank of Pukhach naddi.	A pit a few feet deep was sunk in sandstone showing stains of oil. Only a trifling quantity was obtained.	Sandstone.				
Middle Baránga: north point of island.	Artificial pool through which gas with a little oil rises.	Shale and sandstone.	1			
20 or 30 yards south-east of above pool.	Boring (in progress) on Mr. Dawson's grant.	Ditto	1	76	0	
About $\frac{1}{4}$ mile from shore, $1\frac{1}{2}$ miles north-west of Khiwerua.	Small pool through which gas rises. It is said there are other similar pools in the neighbourhood.	Gray clunchy shale?	1			
200 yards east-north-east of Khiwerua.	Several pools similar to the above. There is a small mud cone here a few yards in diameter, and with a slope of about 15° . The crater is filled with muddy water through which bubbles of gas rise. As the cone is situated in the bed of a nalla, it is washed away every rains.	...	4 or 5			
Western Baránga: $\frac{1}{2}$ mile south-west of Mraingu.	Two borings (in progress) on Mr. Dawson's grant.	Alluvium with shale? below.	2	...	...	Transparent; color of dark sherry.
No. 1.	.	...	...	50	3	
No. 2.	.	.	...	24	1	

Locality.	Character of wells.	Rock in which wells are sunk.	Number of wells.	Depth in feet.	Stated daily yield in bottles.	Color of oil by transmitted light.	Specific gravity of oil at 62° F.
	50 yards to the south of the borings, amidst some rice fields, there is a spot where gas rises, which shows itself during the rains by bubbles. A little saline water issues with the gas, and, owing to the salt, there is a space of some yards around where rice will not grow.						
East coast near south end of island.	Indications of petroleum in three spots at least.						
<i>Krinkwaimau Hills.</i>							
Nagádweung	This name is applied to a natural pool a few yards diameter filled with muddy water, with mud below into which a 15-foot stick can be thrust to the end without difficulty. Gas rises in certain spots in some quantity, and the villagers say that occasionally it is given off in much greater amount.	...	1				
About 250 yards north-west of the above.	Artificial pit partially filled with water, through which some gas and a little petroleum rises.	...	1				
About 70 yards south of above pit.	Bore-hole (in progress)	...	1	32	0		
Near Prairoa	About 1½ miles west of Nagádweung, near the village of Prairoa, there is said to be a pool of the same kind as that at Nagádweung, but of smaller dimensions.						

Limestone is very plentiful in Rámri. One of the most important localities is just north of the Yánthek creek, about two miles north of the village of the same name. The rock there is yellowish-white or occasionally reddish. It is rather brittle, and generally has a tolerably smooth fracture. Some parts have a fine granular structure. It includes strings and seams of calcspar, which weather out prominently from the mass of the rock, but it is free from chert and from interbedded layers of other rock. The bedding is generally obscure, and masses 20 feet thick occur in which none is apparent. In places, however, the rock has a slight tendency to flagginess. The dip and strike seem to be very inconstant. The supply is unlimited. I myself saw the stone to be continuous over an area of many acres, forming rocky hillocks 20 to 40 feet high, and the villagers with me said that it extends over an area four kos in circuit. The limestone is situated close to a tidal creek which joins the Yánthek creek within 200 yards, so that there is great facility for exportation.

The analysis of a carefully chosen average sample, made up of pieces from several of the small native quarries, yielded—

Calcium carbonate	.	.	.	.	94.4
Magnesium carbonate	.	.	.	.	5
Ferrous carbonate (with some Fe_2O_3 & Al_2O_3)	.	.	.	.	1.5
Insoluble (mostly clay)	.	.	.	.	3.6
					<hr/> 100.0 <hr/>

The manufacture of lime is carried on in the neighbourhood, but not on any large scale. The rock is quarried with crowbars and hammers, having been previously heated by brushwood fires: gunpowder is not used. The kilns in which it is burned are circular, about 8 feet in diameter at the top and rather more at the bottom, with a depth of about 10 feet. They are dug out on a steep clay-bank, and have one orifice in front at the bottom about 18 inches diameter. There is a low clay wall round the top.

The lower part of the kiln is filled with logs of wood and the upper with broken stone in pieces up to some inches diameter. After some days, when the fire has burned out, the top portion of the stone, which is only partially burned, is removed separately, and the lime then withdrawn and slaked. Salt water from the creek is used for this purpose, as being the nearest at hand, but it is by no means calculated to improve the lime. The half-burned stone is added to the next firing. The slaked lime is sold at the kilns at the rate of twenty rupees per hundred *mans* (maunds).

Limestone of a very similar character to that at Yánthek also occurs in large quantity near Tsinbok. It is a yellowish-white rock looking like indurated chalk. Besides veins of calcspar it contains an occasional nodule of chert, which I have not observed in the rock at Yánthek. There are at least two outcrops to the south-west of the village, at one of which the limestone forms a hillock 30 feet high. From this alone a very large supply could be obtained, and it is within less than a mile and a half of a tidal creek. The composition of the stone is very similar to that of the Yánthek rock.

Between Tsetamá and Kyauk Tyán a different kind of limestone (p. 192) occurs in practically unlimited quantity. It is remarkable as being an almost pure carbonate of lime, there being hardly any matter in it insoluble in acid, and only traces of iron and magnesia.

Limestone also occurs, although in less abundance, at Thán Chaung, Tengbain, Allé Chaung, Tsúné, and Amherst Island. Doubtless it is to be found on Cheduba also. In the Baránga Islands, however, I observed no calcareous rock anywhere.

Besides true limestone, recent coral, owing to the elevation that the Rámri group of islands underwent during the last century (p. 190), occurs in large quantity along the coast in many places, where there are rocks that afforded the coral animals a secure foundation to build on. Amongst other localities may be mentioned the rocky point west of Kyauk Phyu and the similar point at Likmau.

It will thus be seen that there is an exhaustless supply of lime in the islands conveniently placed for export. Mr. Theobald, also, mentions at least one spot on the coast of Arrakán to the south of Sandoway where limestone occurs in unlimited quantity and in a most favourable position with respect to shipment.¹ It is open to consideration whether the lime of Arrakán could not compete on paying terms in the Calcutta market with the Sylhet lime which is subject to the long and tedious river navigation from Chháta.

In some places, as at Kyauk Tyán and Amherst Island, there are gypseous shales through which crystals of selenite are sparsely disseminated. These are to be found scattered about on the surface of the ground, owing to the weathering away of the rock. It would be difficult, however, to obtain more than a few sérs of them, and as a source of gypsum they are perfectly useless.

It appears from Dr. Spry's paper on Kyauk Phyu written in 1841, that salt was at that time made there from sea water by solar evaporation, and sold by the people to Government at 7 annas a *man*.² The manufacture has, however, been extinct for many years past.

Limpid rock crystals occur in some of the seams of the cherty rock mentioned at p. 192, and are collected sometimes by the villagers. But they are too small to be of any commercial value.

In the twelfth volume of the Asiatic Society's Journal an account is given of an alleged discovery of native copper on Round Island. The specimens were found in 1843 by a Mug who was employed by Captain Williams to search for coal. Captain Williams sent them to Mr. Piddington, who pronounced them to be "nodules of native copper, with red and black oxide and silicate of copper."³ He also speaks of them as "rolled native (virgin) copper" "with a coating of red oxide and the blue and green carbonates."⁴

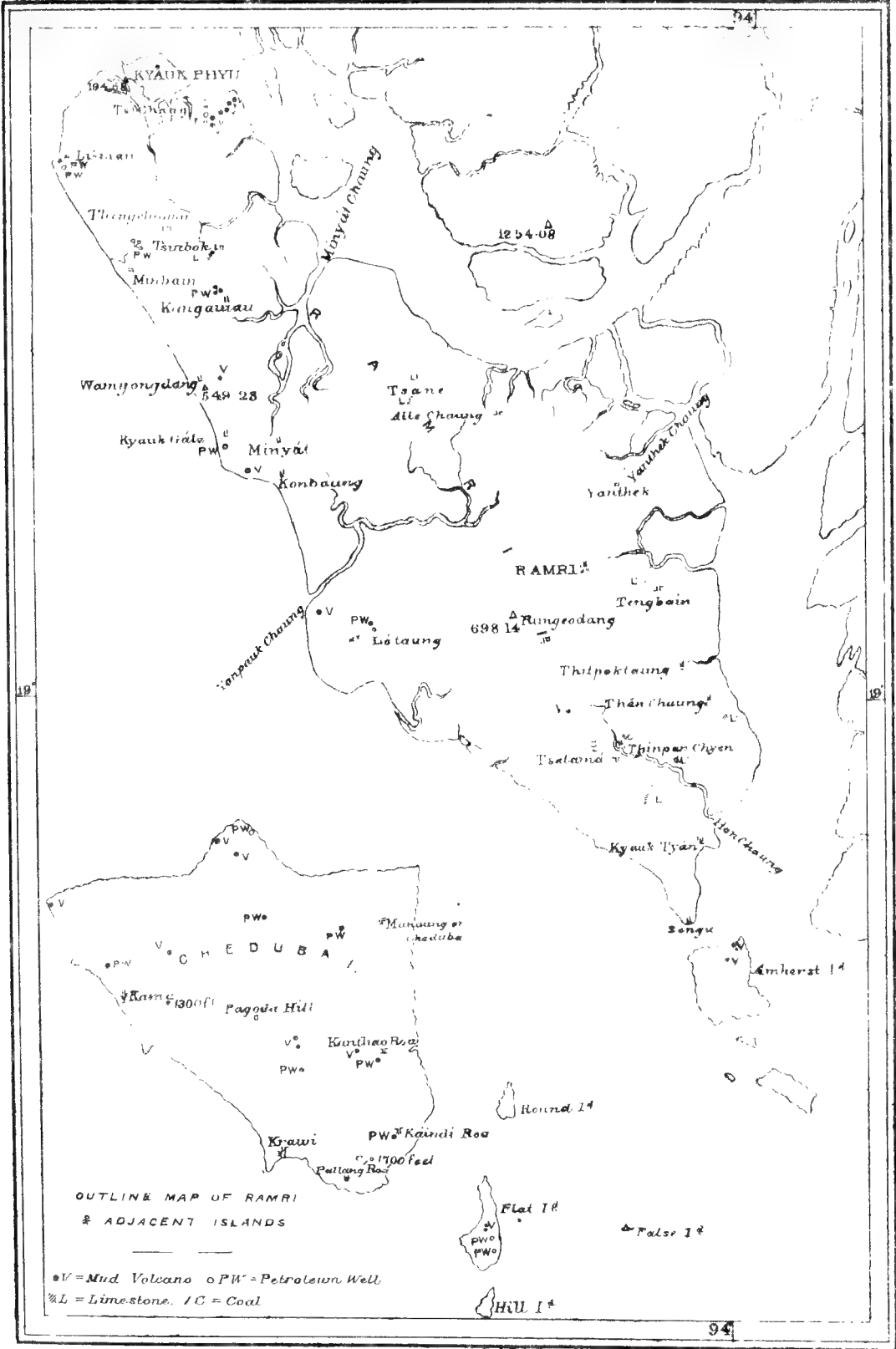
Alleged discovery of copper on Round Island.

¹ Memoirs, X, 345.

² Journ. As. Soc., Bengal, X, 144.

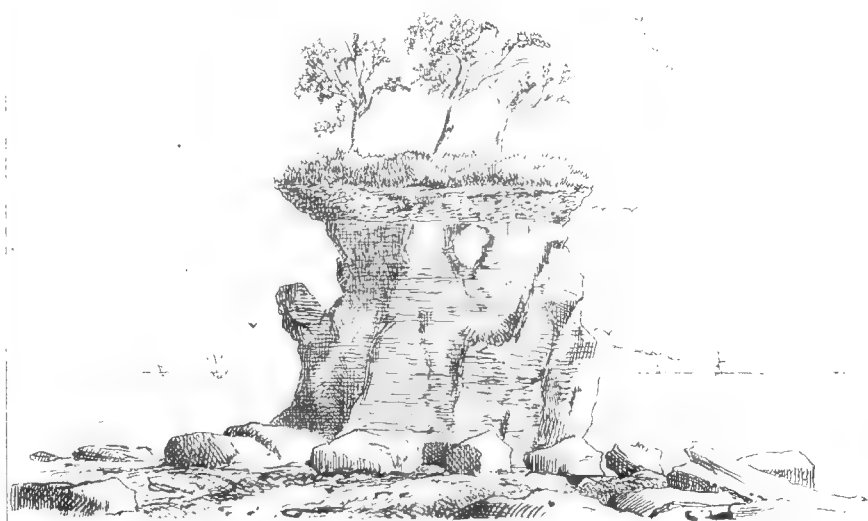
³ Journ. As. Soc., Bengal, XII, 333.

⁴ *Ibid*, 914, 906. A very extraordinary analysis was given by Mr. S. Mornay, who considered the specimens to be an alloy of copper, titanium, mercury, lead, cobalt and iron.





OUTLINE MAP
of
SARANGA ISLANDS
Showing known petroleum localities



Isolated Rock on Sea-beach of Round Island. ~ Present High tide level.
~ ~ ~ mass of recent marine shells six feet above ~

The locality seemed an unlikely one for copper to occur in, but before my visit to the island, the Deputy Commissioner, Mr. Duke, made enquiries on the subject, with, however, a negative result. Subsequently I went to Round Island, and found the hilly ground there to consist, as was anticipated, of stratified rocks similar to those of Rámri and Cheduba, and therefore of presumably early tertiary age. The occurrence of copper in such rocks would be most unusual. No one that I questioned on the subject had ever heard of copper having been found in the island.

Not long ago whilst arranging the series of Indian copper ores in the Geological Museum, I lighted on a tray containing a number of very irregularly shaped pellets from the size of a grain of shot to that of a large pea or more. They were composed of bronze-colored metal with a coating of red and black oxides and green carbonate of copper and with a few rolled grains of quartzose sand adhering to them. The accompanying label ran "Copper ore from Flat Island¹ off the south-east end of Rámri; presented by Captain Williams." On assay, the pellets were found to be an alloy of copper and tin, one which has never yet been found native, but which, artificially manufactured, is used to a considerable extent amongst the Burmese. It is clear therefore, that the metal found by the Mug was not native copper but artificial bronze, which, judging from the condition in which it was unearthed, had probably lain buried for a very long period.

ADDITIONS TO THE MUSEUM.

(FROM JANUARY TO MARCH 1878.)

Donors.

Burmese petroleum, and series of liquid and solid products manufactured therefrom.

THE RANGOON OIL COMPANY.

Specimens of zincblende from near Giridi; argentiferous galena from Phága (seven miles south-east of Danda, Bhágapur District); and gray copper ore with barytes from Jabalpur District.

W. G. OLPHERTS, ESQ.

Copper pyrites in Kaladgi limestone (Madras Presidency).

DR. THORPE.

Two series of minerals (by exchange).

MINERAL DEPARTMENT, BRITISH MUSEUM.

SERIES I.

Aikinite in quartz, Beresowsk, Urals, Russia.

Anorthite, with biotite and pyroxene, Monte Somma, Vesuvius.

„ var. Amphodelite, with pyroxene and copper pyrites, Tunaberg, Sweden.

¹ In the original papers in the Asiatic Journal there is a confusion between Round and Flat Islands—*Vide* p. 904.

- Anthosiderite, Antonio Pereira, Pernambuco, Brazil.
 Aeschynite in orthoclase, Ilmen Mountains, Orenburg, Russia.
 Apatite, massive, Kragerøe, Norway.
 „ „ Lofthuus, Norway.
 „ var. Phosphorite, Estramadura, Spain.
 Arseniosiderite, Romanèche, Saone et Loire, France.
 Alunite in crystals and massive, Tolfa, near Civita Vecchia, Rome.
 „ massive, Bereghszasz, Hungary.
 Aurichalcite, with calcite, Matlock, Derbyshire.
 „ with wad, Monte Poni mines, Sardinia.
 Berzelianite in calcite, Skrikerum mines, Småland, Sweden.
 Boulangerite, with galena, Ober-Lahr, Rhine.
 „ „ Sala, Sweden.
 Beudantite in interstices in limonite, Montabaur, Nassau.
 Biotite, with hornblende and augite, Monte Somma, Vesuvius.
 „ from the granite of Lake Baikal, Irkutsk.
 „ with muscovite and orthoclase, Ilmen Mountains, Orenburg, Russia.
 Brochantite, with quartz and limonite, Roughten-Gill, Cumberland.
 Covellite, with calcite and massive gersdorffite, Sangerhausen, Thuringia.
 Calomel in crystals, with ochreous limonite on a micaceous sandstone, Moschellandsberg, Rhenish Bavaria.
 Cotunnite on a scoriaceous leucite lava, Vesuvius.
 Chiolite, Ilmen Mountains, Orenburg, Russia.
 Chrysoberyl, with manganese-garnet, smoky quartz and albite, Haddam, Connecticut, U. S. A.
 „ with garnet and mica in quartz, Marschendorf, Moravia.
 Cervantite pseudomorphous after stibnite, with crystalline massive ditto, Borneo.
 Crocidolite, Asbestos Mountains, Orange R., South Africa.
 Cancrinite (yellow), with ekeolite, mica and felspar, Marienskoj mine, Tunkinsker Mountains, Lake Baikal.
 „ (pinkish), Ilmen Mountains, Orenburg, Russia.
 Cronstedtite, with quartz, chalybite, copper pyrites, chlorite and mispickel, Cornwall (mine not yet ascertained).
 „ with limonite in iron pyrites, ditto.
 Chloritoid, with quartz on a gneissoid rock, Pregratten, Pusterthal, Tyrol.
 Chamoisite, Chamoison, Wallis, Switzerland.
 „ var. Berthierine, Bourgogne, France.
 Clinoclase, with wad on quartz, St. Day, United Mines, Cornwall.
 Coquimbite, with copiapite and chalcantite, Copiapo, Coquimbo, Chili.
 Domeykite, Copiapo, Chili.
 „ var. Condurrite, with cuprite, Condurrow mine, near Redruth, Cornwall.
 Dipyre, Vallée de Castellon, St. Giron, L'Ariège, France.
 Dechenite, Freiburg, Baden.
 Enargite in crystals, with copper pyrites in a silicious matrix, Parad, Tatra Mountains, Hungary.

- Enargite crystalline massive, with copper pyrites in a silicious matrix, Parad,
Tatra Mountains, Hungary.
- Euphyllite, with tourmaline, Chester Co., Pennsylvania, U. S. A.
- Euchroite, on mica-slate coated with ochreous limonite, Libethen, Hungary.
- Epsomite, Calatayud, Aragon, Spain.
- Ekmanite, Brunsjö iron mine, Arebrö Län, Grythytte, Sweden.
- Fergusonite in quartz, with black mica and a little felspar, Ytterby, Sweden.
- Fibroferrite, Copiapo, Chili.
- Greenockite, with calcite and chlorite, near Bishoptown, Renfrewshire, Scotland.
- Glaucodote, with copper pyrites, Hakansboda, Sweden.
- Gearsutite, with chalybite in cryolite, Evigtok, Arksut-Fjörd, West Greenland
- Hessite or Petzite, Sawodinskoi mine, Altai.
- Hydrotalcite, with serpentine, Snarum, Norway.
- Herschelite, with phillipsite and mealy zeolite in cavities in a lava, Aci Castello,
near Aci Reale, Sicily.
- Hydrophite, with serpentine, Taberg, Wermland, Sweden.
- Hjelmite in albite, Fahlun, Sweden.
- Hatchettite, with chalybite, bitumen and quartz in cavities in clay iron-stone,
Merthyr Tydvil, South Wales.
- Jadeite, China.
- Jefferisite, Westchester, Pennsylvania, U. S. A.
- Knebelite, Dannemora, Sweden.
- Killinite in granite, Killiney Bay, Co. Dublin, Ireland.
- Karstenite, Schaffhausen, Rhine.
- „ Gmünden, Austria.
- „ with salt, Salzburg.
- „ with hematite, Hall, Tyrol.
- Lead (native), in granular hausmannite, Pajsberg iron mines, Philipstadt,
Wermland, Sweden.
- Levyne, with mesolite in cavities in a trap rock, Little Deer Park, Co. Antrim,
Ireland.
- Liroconite, with clinoclase, St. Day, United Mines, Cornwall.
- Lanarkite, with leadhillite, caledonite, cerussite, and pyromorphite, Leadhills,
Lanarkshire.
- Minium, The Eifel, Rhenish Prussia.
- Meliphanite, with mica and allanite in felspar, near Frederikswärn, Norway.
- Mellilite, with pseudonepheline and apatite on dolerite, Capo di Bové, near Rome.
- „ Monte Somma, Vesuvius.
- Mosandrite, with black mica in zircon syenite, Langesund Fjörd, Brevig, Norway.
- Megabasite, with fluor and molybdenite in quartz, Schlaggenwald, Bohemia.
- Manganocalcite on quartz, Schemnitz, Hungary.
- Nagyagite, with müllerite, and quartz, mingled with rhodochrosite, Nagyag,
Transylvania.
- „ in crystals, with quartz, blende, and rhodochrosite, ditto ditto.
- Natron, Egypt.
- Ozokerite, Gallicia, Poland.

- Perofskite, with clinochlore in crystalline limestone, Achmatowsk, Urals.
- Pyrochroite in magnetite, Pajsberg iron mines, Philipstadt, Wermland, Sweden.
- Phenakite, with small crystals of quartz in an ochreous limonite, Frammont, Vosges.
- „ in bright crystals on an albitic granite, Ilmen Mountains, Orenburg, Russia.
- Phenakite from the emerald mines of Ekaterinburg, Perm, Russia.
- Pyrosmalite, with hornblende on magnetite, Nordsnarken, Wermland, Sweden.
- „ with hornblende and chlorite on magnetite, ditto ditto ditto.
- Penninite, partly encrusted with small crystals of garnet, Zermatt, Switzerland.
- Prochlorite, with copper pyrites and quartz, Cornwall.
- „ with dolomite on magnetite, Traversella, Piedmont.
- „ var. Ogcoite, St. Gotthard, Switzerland.
- Pharmacolite, with erythrite on carbonate of lime, with galena, Wittichen, Baden.
- Predazite, Predazzo, Tyrol.
- Römerite, with copiapite and chalcantinite, Copiapo, Coquimbo, Chili.
- Ratholite or Pectolite, Ratho quarry, near Edinburgh.
- Retinasphalt, Bovey Tracey, Devonshire.
- Sternbergite, Joachimsthal, Bohemia.
- Sylvanite, with drusy quartz on a trachyte porphyry, Offenbanya, Transylvania.
- „ var. Müllerite, with blende in a brecciated siliceous rock, Nagyag, Transylvania.
- Sal Ammoniac in crystals on a scoriaceous dolerite lava, Vesuvius: Eruption, November 1868.
- Sarcolite, with pyroxene, Monte Somma, Vesuvius.
- Staurolite, with kyanite and mica in paragonite slate, Giornico, Levantino Valley, Tessin, Switzerland.
- „ with garnet in mica-slate, Taganai, Urals.
- Sapphirine, with mica, Fiskenaes, Greenland.
- Schrötterite, Libethen, Hungary.
- „ near Tavistock, Devonshire.
- Scolecite, Berufjörd, Iceland.
- Smectite, Kreuznach, Rhine.
- Samarskite in granite, Ilmen Mountains, Orenburg, Russia.
- Sordawalite, Sordawala, Finland.
- Tallingite, with atacamite and wad, Botallack mine, St. Just, Cornwall.
- Ullmannite, with chalybite and copper pyrites, Siegen, Prussia.
- Ulexite in gypsum, Brookville, Hants Co., Nova Scotia.
- Voigtite in graphic granite, Manebach, Thuringia.
- Vauquelinite, with crocoisite, pyromorphite, cerussite pseudomorphous after galena, limonite pseudomorphous after iron pyrites, and quartz, Beresowsk, Urals.
- Volborthite, with wad on Permian sandstone, Ivanow's copper mine, Perm, Russia.
- „ on limonite, Sissersk, near Nijni Tagilsk, Perm, Russia.
- Wehrlite, Szurraskö, Hungary.

- Wöhlerite, with elcöelite and cancrinite in zircon syenite, Langesund Fjörd, near Brevig, Norway.
 Wagnerite, with brown-spar in a greenish clay-slate, Höllgraben, near Werfen, Salzburg.
 Walchowite, Walchow, Moravia.
 Xenotime, with yellow and black yttrotantalite in felspar, Ytterby, Sweden.
 Zippeite, with small crystals of selenite, Wheal Edward, near St. Just, Cornwall.

SERIES II.

- Albite, with malachite and chessylite, Kirabinsk Mine, Ekaterinburg, Russia.
 Albite, with chalybite, Zillerthal, Tyrol.
 Andalusite, Brazil.
 Aragonite in twinned crystals, Bilin, Bohemia.
 Arsenic (native), with calcite, Andreasberg, Hartz.
 Avanturine quartz, Cape de gata, Spain.
 Barytocalcite in crystals and massive, Alston, Cumberland.
 Calcite in fascicular groups on quartz, with blende and galena, Schemnitz, Hungary.
 Calcite on fluorspar, near Camborne, Cornwall.
 Cadmiferous blende, Przibram, Bohemia.
 Chesterlite in granular dolomite, Chester Co., Pennsylvania.
 Chiasolite in clay-slate, Lancaster, Massachusetts.
 Chrysolite in crystals, The Levant.
 Corundum crystal, Tibet.
 „ „ Salem, Madras.
 Dolomite, columnar, with dendritic manganese oxide, Sunderland.
 Fassaite in blue calcite, Fassa, Tyrol.
 Fahlunite in talc slate, Fahlun, Sweden.
 „ „ with copper pyrites, Fahlun, Sweden.
 Felspar (compact), colored in spots with manganese oxide, Charlotte, North Carolina.
 Fire opal, Zimapan, Mexico.
 Green tourmaline, with sapphire in granular dolomite, Campolongo, St. Gotthard, Switzerland.
 Grossular garnet, Fassathal, Tyrol.
 Grossular in loose crystals, Wilui R., Trans-Baikal.
 Gurhofite, Gurhof, Styria.
 Humite, with biotite and calcite, Monte Somma.
 Hyposclerite, with melanite, Arendal, Norway.
 Leelite, with actinolite, Salberg, Sweden.
 Limonite, fibrous and compact, Orkney Islands.
 „ „ Siegen, Prussia.
 Mesolite, with thomsonite and stilbite, Renfrewshire.
 Moonstone, Ceylon.
 Murchisonite, Heavitree, near Exeter, Devon.

- Natrolite, with analcime on basalt, Auvergne.
 „ in a cavity in basalt, Leipa, Bohemia.
 „ with gmelinite in trap rock, Co. Antrim.
 „ on phonolite, near Aussig, Bohemia.
 Omphacite, with garnet, Sau-Alpe, Carinthia.
 Orthoclase (massive), Frederikswärn, Norway.
 Petalite, with lepidolite, Island of Utö, Sweden.
 „ with spots of indicolite, Island of Utö, Sweden.
 Physalite, Trumbull, Connecticut.
 Prase, Breitenbrunn, Saxony.
 Pyrolusite, coating stalactitic psilomelane, Thuringia.
 „ Nassau.
 Pyrophyssalite in quartz, Finbo, Sweden.
 Pyrophyssalite, Finbo, near Fahlun, Sweden.
 Pyroxene, with hornblende, Arendal, Norway.
 Quartz, pseudomorphous after chalybite, Cook's kitchen mine, Cornwall.
 Richterite, with schefferite and hematite, Langbanshyttan, Sweden.
 Rubellite, with indicolite and green tourmaline, in albite, Chesterfield, Massachusetts.
 „ Elba.
 Sahlite, with galena and calcite, Sala, Sweden.
 „ with hornblende and sphene, Arendal, Norway.
 Schefferite, with rhodonite, Langbanshyttan, Wermland, Sweden.
 Siliceous sinter, The Geysers, Iceland.
 Spinel (blue), with hornblende and mica in limestone, Aker, Sweden.
 Tasmanite, Mersey R., North Tasmania.
 Topazolite, with muscovite, Mussa, Piedmont.
 Wood-tin, near Truro, Cornwall.
 „ in water-worn fragments, Cornwall

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April 24th, 1878.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 3.]

1878.

[August.]

NOTE ON THE PROGRESS OF THE GOLD INDUSTRY IN WYNAD, NILGIRI DISTRICT, MADRAS PRESIDENCY, by W. KING, B.A., *Deputy Superintendent, Geological Survey of India.*

The official boundaries of Wynád having of late been altered by the annexation of its south-eastern frontier, or the country around Dayvallah, to the Commissionership of the Nilgiris, it becomes necessary, as in the heading of this paper, to refer to the present area of the gold industry as being in the Nilgiri district, instead of as hitherto in that of Malabar.

It is now nearly three years since my first notice¹ was written on the gold-fields of Wynád, at which time a commencement was about to be made by the pioneer Alpha Gold Company in working them. Since then two other Companies, the 'Wynád Prospecting' and the 'Prince of Wales' Tribute,' have made essays with the same intention; but none of these have, until very lately, succeeded in obtaining from the quartz an average percentage of gold at all equalling that of my preliminary crushings, namely, 7 dwts. to the ton. It is only within the last few months that some stone from 'Wrights' level' in the Alpha works has yielded from 11 to 17 pennyweights.

The returns obtained were all so much below the amount expected, that I was, at various times, applied to by those interested in the successful working of these Companies for any suggestions as to improved manipulation, or better mining; and in July last I made a hurried inspection of the works and the machinery.

In all cases, the mining had only been carried on near the surface; and in most instances disappointing results had driven the Managers and working Directors from one point to another of the reefs, as more or less promising stone seemed to present itself to the search. The Alpha Company was at a standstill through exhaustion of funds and breaking down of machinery; the Wynád Prospecting Company had nearly run through its capital, but hoped to be able to hold on by obtaining gold sufficient to pay working expenses; and the Prince of Wales' Company, which has no machinery of its own, had leased that of the Alpha Company,

¹ Records Geol. Surv. of India, Vol. VIII, Part 2.

and was collecting stone in readiness for crushing as soon as this machinery should be again in order.

Through the kindness of the Managing Directors, I have been supplied with the tables and statistics given in this paper; and these will show what the results have been up to date. They do not, however, show how and whence the stone was obtained, or the style of machinery used; I therefore enter into some detail in this paper regarding these two points.

The main results of the gold workings up to date are, as nearly as can be made out—for no correct returns were kept at first—that the gross amount of gold obtained by the three Companies up to the 14th of March 1878 is 271 oz. 9 dwts. 14 grains: the average yield of gold per ton of quartz on all this amount has been 4·5 dwts.; and this gold has been sold at prices varying from Rs. 40 to Rs. 45 the ounce. This low average yield is calculated on the whole absolute tonnage of quartz extracted in Wynád; but it is only fair to give the following averages for each Company's working:—

Alpha Company	...	769·5 tons	gives 2·27 dwts.
Wynád Prospecting Company	...	99·85 „	„ 3·02 „
Prince of Wales' Company	...	322·66 „	„ 10·5 „

Regarding the 'touch' of the gold, I have only two quotations from the Wynád Prospecting Company, namely:—"It varies much in quality, running from 5½ to 9; Mr. Orr values the worst at Rs. 36 per ounce." Mr. Orr, whose firm of jewellers in Madras has purchased most of the Wynád gold, writes me:—"The gold is of good quality, better than *sooga* gold,¹ for which we have paid Rs. 45 per ounce."

The country around Dayvallah is much broken up into low grassy hills and ridges, varying in height up to 300 feet, on the summits and crests of which the quartz reefs generally occur, and the valleys between these all lead into the great 2,000 feet deep Carcoor cherrum, or valley, of the Western Gháts, or into the smaller cherrums to the west of Dayvallah. The mines of the original workers, or the Korumber excavations, and even those of the latest European explorers, have all been run into the slopes of these small hills, or into the sides of the great cherrum; but very few of these have been driven at the lowest levels, or from the beds of the streams between the hills. Indeed, I doubt whether any workings have been excavated below the levels of these streams, except perhaps in the sides of the Carcoor valley; and there is no known instance of shafts having been sunk to the depth of the permanently water-holding country-rock, below that zone of variable thickness into which atmospheric influences are supposed to extend.

It is not here intended, after the popular cry, to imply that mining ought to have been carried to any extraordinary depths, such as the 7 or 800 feet levels of Australia, where working was in most cases only rendered necessary by the lodes having been worked out to these depths; nor is it an ascertained rule that richness

¹ Among native goldsmiths there are ordinarily three qualities of gold, of which "*sooga*" is the medium

of veins almost always increases with the depth; but it is almost certain that displacement and non-continuity of reefs must be expected in so much of the country-rock as is exposed to atmospheric influences, and these defects would of themselves be sufficient to prevent steady and successful mining being carried on to any great extent at all near the surface. Local displacement can of course, as a general rule, only have taken place near the surface; but as this surface in Wynád is a very uneven one, such breaks must be expected in most of the ridges and knolls of the Dayvallah country, and to a much greater extent on the great slopes of the Gháts. There is even a case in point in the Prince of Wales' Company's claim, where, on the east side of the ridge north of the Alpha works, a tunnel was driven with the expectation of cutting the northern course of the Skull reef on the prevalent eastward dip, but without success. It was then conjectured, from an outcrop of quartz on the south slope of this ridge, that the reef dipped quite in the opposite direction or westward, and a new tunnel was proposed.¹ The reef shows very well on the top of the ridge, lying at a very low angle to the eastward, but it has a tendency to resume the higher normal dip (25° to 30°) lower down the slope. From all I could see, the very low dip on the summit of the hill appeared to be due to a sinking down of the reef on the weathered and denuded foot-wall, while the abnormal lie of the outcrops of quartz on the lower slopes is most likely attributable to local displacement of the country-rock, very large and old slides of decomposed gneiss being not at all unfrequent in this part of the country.

It has been found that the reefs continue to the deep so far as workings have been carried out; but as these are of little depth, the country itself can only be looked to for evidence of any value on this point. Certainly many of the reefs can, on the upland, be seen to run deeper than the Skull reef; while outcrops are known to exist far down in the deep Ghát valleys, which to all appearance are the continuations of reefs on the upland; and it seems hardly probable that reefs which are traceable for miles in their strike can be so very limited in depth. There must, no doubt, be cases of thinning out, and it may be so in the case in question to some extent; but the evidence is against this, for some part of the reef (slipped or *in situ*) has been struck in the last attempt to reach it; though, even if it had not been struck, there would have been no clear proof of its entire absence, considering that the tunnel has such a small section, and that reefs are often capricious within small ranges. But it is a most common experience in this part of Wynád to find the reef outcrops much tumbled and slipped at various points among the ridges in the upland; and seeing that here, well up the sides of the hill in question, there are large outcrops of quartz in untoward

¹ This was at the time of my visit in August last; but it appears that no further attempt was then made to strike the reef, all efforts having been directed to the raising of stone from another more accessible part of the Skull reef. In the last report of this Company it is stated that another endeavour was made at the Prince of Wales' reef so late as the 1st of January 1878; but that as the old workings had completely fallen in, it was necessary to begin a fresh tunnel, and that the reef was only struck ten days before their lease expired. The length of the tunnel is given as 132 feet from entrance and about 50 feet in depth from surface; but there are no further details as to direction or position.

positions, one showing a westerly dip, I am the more inclined to view the case as one of displacement, in preference to one of sudden absence of the reef altogether over any appreciable area.

A further source of disappointment in the present system of mining may also, I think, lie in a possible mechanical distribution of some of the gold irregularly throughout the reefs by the mere percolation of water in this zone of varied decompositions; and that thus the gold may be found not only more fitfully distributed than is at times usual with the precious metal, but even to some extent washed out of the reef. Although there is no certain evidence that gold may be thus distributed through reefs, the possibility of such a mechanical process seems quite conceivable when the conditions of some of the reefs and their gold are considered in conjunction with the effects of such an exceptionally moist climate as that of Wynád, where the movement of water underground must be proportional to that on the surface. The quartz of many reefs, as far as is disclosed by the old excavations, and later by recent workings, particularly in the Skull reef, is much fissured and very often minutely, and even in part continuously, cavernous, or, again, quite crumbling and rotten from having been so largely charged with sulphides, while the gold left is generally in a minute state of division; and throughout this style of vein-stone there is tolerably free percolation of water in quite sufficient force to carry off minute gold. In nearly all the old excavations which I examined, and some of these are at the base of the Dayvallah ridges, water was dripping freely from the exposed surfaces of quartz. Nearly all the long outcrops of the reefs are really just catch-surfaces for water; while the reefs themselves and their clayey selvages must be, in many instances, only so many channels for the flow of water through the zone of decomposed rock. Among other modes of occurrence, the gold is found in empty cavities, once also occupied in part by sulphides, which have left their impressions on the quartz; or it is intimately associated with sulphides in partially filled cavities; or, again, it and the sulphides fill up such hollows. In the first and second cases, more or less sulphides have been removed, more generally by solution, but still to some extent mechanically; most likely as fine ochre. The gold associated with these was then either left behind, as is often the case, or it might, if minute enough, have been carried along with the solutions, or subsequently, by the ever-recurring passage of water, to be caught again in favourable hollows, or collected in and against the clayey casing,¹ or gravitated to the plane of constant saturation, or finally, carried out altogether by springs in the Gháts.²

With the possibility, then, of such a secondary distribution of part of the gold, and an extreme probability of encountering more or less disturbance of the reefs, in the ground within the reach of atmospheric influences, it becomes an important question how far those influences may extend beneath the surface, or, in

¹ The frequent richness of casing and wall-rock, though generally accounted for by chemical action, may be in part also due to this, as it were, secondary process of distribution; for there is free gold here as well as in the veins.

² For some interesting remarks upon the possible removal of gold by solution, see Raymond's Mining Statistics West of the Rocky Mountains (1871), p. 508.

other words, at what depth the plane of constant saturation may be supposed to lie. It may, at all events, be concluded from the old excavations in the country-rock, debris of which is still frequently found at their mouths, and from the lately driven tunnels, which were mostly in tough clay (decomposed felspathic gneiss), that varied decompositions penetrate throughout a great portion of the upland country to the level of lowest drainage, that is, occasionally for 300 feet; and on this it is reasonably inferrible that weathering extends nearly as deep again in the neighbourhood of the main upland streams, and far inward horizontally on or near the edges of the Ghát slopes. Thus, arguing from the depth to which these influences extend on the upland, I should be inclined to look for the plane of constant saturation at 200 feet below, and 600 feet inwards from, the level of the edges of the Gháts. Further inland, the vertical depth might be taken at 100 feet.

At the same time it is, as has been shown by the late success of the Prince of Wales' Company, always possible that rich finds may be met with, the theory of fitful secondary distribution even meeting this view within the zone of variable decompositions; but these will be at the best but of importance in small adventures, such as those which have up to the present time been carried on in Wynađ.

The Alpha Company opened up a large quartz 'boil,' or massed assemblage of veins, called the Skull reef, not far from the site of their machinery, the stone having been collected partly from the surface, and partly from fresh excavations in the old mines of the Korumbers. An adit was run, without any careful consideration as to direction, into the west side of the hill, with the hope that the reef might be cut somewhere about the lowest level of the old Korumber workings; but this was abandoned after a time. This excavation showed, at any rate, that driving will not be a very expensive item in the gold industry, as the rock is very largely weathered into a soft, more or less felspathic, clay, with occasional masses of undecomposed rock; but timbering is absolutely necessary to guard against the very frequent slipping of this clay. Then, as there had always been a desire on the part of the Manager (Mr. Withers) to drive at the southern outcrop on the steep slope of the Ghát, a tunnel was run in for a short distance at 'Wrights' level,' though still at a considerable height above the limit of permanent saturation, and well within the range of atmospheric influences. It is, however, from the same Wrights' level that the rich stone worked by the Prince of Wales' Company was subsequently obtained.

The want of success in the operations of the Alpha Company may be attributed, I think in great part, to the following causes. First, bad selection of stone. That there is very good stone in the reefs of the Alpha concession is proved by the later crushings of the Prince of Wales' Company. Second, unsystematic working of the reef or reefs, as exemplified in the fitful manner of taking stone from open quarries at the surface and from the different drifts, according as fancy led the authorities. Certainly better returns than those obtained might have resulted from one steadily-pursued tunnel and side galleries; while they could not have been worse than those got on the desultory plan of working.

Third, the proper amount of stone was never either mined or crushed in the time estimated for a paying result. The engine was overestimated in its power, and the 15 stamps were never worked at once; while the calculation was that, with 15 stamps, 15 tons of quartz could be crushed in the day's work. As it is, according to the returns supplied to me by the Alpha Company, I find that had their work been at the rate originally proposed, even under their small general average, the working of the mine would not have been a failure. The cost of raising and crushing $769\frac{1}{2}$ tons of quartz was Rs. 2,971-0-5; and taking the value of their gold at Rs. 45 per oz., which is about what was paid for it, the amount realised on 91 oz. 12 dwts. 23 grains, or about Rs. 4,224-0-0, leaves a value of Rs. 1,252-11-0 for other expenses, besides raising and crushing. It is true that parts of eight months were occupied in this crushing, but the work ought all to have been done in two months and a half, reckoning 20 working days to the month; and had the work been properly done, it is almost certain that the cost of raising and crushing would not have been so high as it is set down in their table, the average cost of raising and crushing the quartz being Rs. 3·86 per ton, a far too high rate for Wynád mining.

The next adventure is that of the Wynád Prospecting Company, which has been carried on in a very small way with the intention of making preliminary trials as to the paying capabilities of the reefs. The works are situated on the edge of the Carcoor cherrum, near the outfall of one of the minor streams of the Dayvallah country, so as to take advantage of the water-power, while the reefs worked are also close by. In the case of this undertaking also, the mining has not been systematic, nor has it been carried to any depth in the hillside or downward. Of the reefs taken up by this Company, the Monarch was tried by a shaft and level drift run into the eastern side of the hill through which the reef runs, but was given up at 55 feet, as the lode was not struck, as had been expected, if the dip of the reef had remained constant. Operations were then confined to the Hamlin, Bear, Korumber and Etacull reefs, where they crop out on the edge of the Dayvallah plateau, or at the top of the northern slope of the Carcoor cherrum, and where there is an extraordinary number of old shafts and excavations of the old gold-diggers. It was from among the leaders of these reefs, in the soft decomposed felspathic gneiss, that lumps of quartz with visible gold associated with nests of limonite were obtained.

The Prince of Wales' Tribute Company was started on a very small scale, perhaps more with the idea of keeping the gold industry before the public. The mines, machinery, &c., of the Alpha Company were taken on a tribute for a certain period, and operations were commenced with stone from the old quarries of the Alpha works. A commencement was also made on the northern extension of the Skull reef in a high hill between the works and Dayvallah village, but the excavations were stopped owing, as already stated, to the reef not being struck at the expected distance, though the search was afterwards resumed, and the reef found just before the lease had expired. However, a persistent drive at Wrights' level resulted in a find of rich stone, which continued to give good results, until March last, when the operations were discontinued.

The capital of the three Companies has thus been expended on what must be considered mere scratchings below grass, from which of course it was always possible that local rich finds might have been secured; as it is, no rich shoot of gold was struck until very lately, or until the capital and patience of the pioneer explorers was to all appearance worn out. It is evident however, from the latest reports of the working of the Prince of Wales' Company, that a rich vein has at length been struck, which may in its continued development fulfil all the promise of this new gold field.

At the Alpha works, there is a stamping apparatus of 15 stamps, arranged in three batteries of the ordinary kind used in Australia, whence this one was also procured. The batteries are driven by a 15 (nominal) horse-power locomobile, the fuel for which is obtainable in the forests close by. It is worthy of notice that this engine has never worked up to the power stated, various reasons being given for this, as that it was a secondhand English engine sent from Australia, or that the fuel was damp, both of which reasons are presumably fair. There is no doubt of the deterioration of fuel, there being no sheds for its storage, as should be the case in a climate like that of Wynád. However, I am firmly convinced that such a costly item as fuel, even in Wynád, should never be included in a scheme for working the gold when there is water-power sufficient for the purpose.

From the batteries, the crushed material is passed over copper¹ tables, mercury troughs, and blanket tables, after which the tailings are treated in a pulveriser. It was found, however, that complete extraction was not effected in the pulveriser, or, as it might more properly be called, amalgamating pulveriser, for much float-gold and gold associated with sulphides, which ought to have been taken up by the mercury, passed away with the slime. A reverberatory furnace was then constructed, in which the tailings were roasted and again pulverised, with somewhat better results; though even after this a perceptible amount of gold could always be shown by washing, and secured by hand-rubbing with sodium-amalgam. It was at the same time found, and experience in the other workings has since verified this, that sodium-amalgam should be used as much as possible, instead of simple mercury, in the extraction of Wynád gold. In the pulveriser, the tailings are made to pass between the grinding wheels and the bevelled edge of the circular pan in which they revolve, while the mercury lies at the bottom of this edge, just below the grinding surfaces; and thus the slime and sand are only ground finer, and then brought in contact with the mercury by agitation alone, which is not sufficient for amalgamation from these tailings, considering that they are so largely made up of sulphides and other ferruginous impurities; while with this, the mercury is so liable to "flour" and become granular, and thus incapable of taking up the minuter gold. Continued observation and experience show that a process analogous to hand-rubbing in the washer's dish is necessary for the saving of minute gold; hence the pulveriser should have the property of grinding the slime in intimate contact with the mercury, as in the ordinary

¹ These tables were subsequently, as they should have been in the first instance, coated with sodium-amalgam.

'arrastre,' or else a rubbing apparatus should succeed it in the process of extraction.

At the time of my last visit, the Alpha works were at a standstill, several repairs being in course of operation, and the engine waiting for some fitting to the boiler. The Manager, however, passed several samples of ordinary burnt tailings through the hand-process which clearly showed gold, only part of which was, however, taken up by even the sodium-amalgam, and there was always colour of gold to the last of the rubbing.

The works of the Wynád Prospecting Company are planted a short distance down the slope of the Carcoor cherrum, and a wire rope, some 400 feet long, is stretched from the entrance of the galleries to the works, along which the baskets of vein-stuff are shot to a kiln, where the stone is burnt prior to being the more easily broken up and tipped into the feed-box. The machinery consists of a Husband's pneumatic stamper, driven by a turbine having a fall of about thirty feet of water, and capable of crushing half a ton in eight hours, the working of these being remarkably easy and constant, requiring only such care as a well-trained native and his assistants can give. From the stamping box, the fine sandy slime passes over a series of two amalgamated copper tables, with a mercury trough at the end of each, whence it flows by a spout to the top of the hollow vertical shaft of a grinding concentrator. The bottom of this shaft is screwed into a muller (continuously hollow with the shaft), or inverted truncated cone, revolving inside of a fixed pan, the lip of which is level with the upper edge of the muller. After passing down the shaft, the stuff is ground only in a very inefficient manner in the pan and then agitated, but not rubbed intimately with the mercury, which lies at the lowest level, or out of reach of the grinding surfaces. This defect might certainly be obviated to some extent by filling up the pan with a sufficient quantity of mercury; but this was not found practicable at these works; indeed, this apparatus was found to be of so little use either in grinding or concentration, that its employment was discontinued. To a certain extent, as its name implies, this machine is a concentrator; for the gold and the auriferous sulphides must, perforce, remain at the bottom of the pan longer than the rest of the crushed material, which is carried away by the water; and in this way freer scope is given for amalgamating, but effectual amalgamation, as far as Wynád gold is concerned, is not secured by such poor grinding and agitation.

There is here, in fact, very much the same defect as in the Alpha machinery; in both cases there is a machine which was expected to grind and amalgamate, but the grinding is only well done in the Alpha pulveriser, while no effectual amalgamation takes place in either apparatus. From the pan the stuff passes over a further copper table into a transverse trough, with a further and last supply of mercury. A horizontal pipe, the under-surface of which is perforated, runs along near the bottom of this trough; water is turned on through the pipe with considerable force, and by its rush among the materials at the bottom a violent agitation is caused, the lighter sand is driven off, and a partial concentration is effected in contact with the mercury. Beyond this, a further series

of sloping buddles and riffled troughs intercept the sulphides, until the tailings finally fall into the catch-pit. Here, also, it was found necessary to construct a furnace for the roasting of the tailings, which were again passed through the whole process, commencing with the stamping box; the results were not satisfactory, though the tailings clearly showed an appreciable quantity of gold, much of which, however, could not be saved by the apparatus provided. As usual, hand-grinding and amalgamation gave the best returns; and thus it is evident that a rubbing machine¹ is required, in addition to a pulveriser. Two assays of hand-ground tailings from the reverberatory furnace were very satisfactory, giving averages of 11·66 dwts. and 6·12 dwts. to the ton. Such roasted tailings as I saw at these works were all so stony and slaggy, that they appeared to have been rather smelted than roasted, and were quite as hard as the original vein-stone. Authority on this point appears always to indicate a bright red heat as the limit of roasting, and that the roasted material can be broken up without such force being required as that of the stamper; though of course it should be submitted to this, in order to reduce it sufficiently for the pulveriser. It is also advised² that the tailings should be freely exposed to the action of the atmosphere for some months in thin layers, and not piled up in pits, as is the case in the Wynaúd works.

The Prince of Wales' Company, as already stated, made use of the Alpha mill; but fortunately the stone raised was rich enough to dispense with extraordinary care in the concentration and amalgamation, which hardly could have been arranged in the time allowed during the lease, or with the small capital at their disposal. Under this administration it was found that the working-power of the driving engine was only sufficient for the crushing of seven tons per diem, or about half the rate originally calculated on.

The following tables are from the published returns of the Companies, or from returns which have been supplied to me by the Managing Directors; and, from my personal knowledge of all the gentlemen concerned, I believe that they have furnished these returns with a firm determination to let the true tale of their efforts be known. Until lately, all these efforts have been unattended with the success they deserved, and no gain has been made, except by the latest adventure, which has had the enormous advantage of working with machinery ready at hand. So far, the work of the latter Company has been crowned with what may be called a success; for, in November last, 50 tons gave an average of over 11, while, in December, 50 tons gave an average of 17 pennyweights, thus showing a decided tendency in the quartz to come up to my average, if not to exceed it.

In the beginning of this paper, the average percentage of gold is given for all the quartz crushed, which is really the truest test of the capabilities of a gold-field; otherwise, between isolated and short operations of particular adventures, where can a line be drawn from which an average should be reckoned? But this generalisation for a whole field is obviously unfair to an

¹ Such a machine is described in the last edition of Raymond's Mining Statistics West of the Rocky Mountains.

² Quartz Operator's Hand-book, Randall, New York, 1871.

adventure which has given averages, for large quantities of stone, exceeding those attained in the earlier trials. I would therefore here record a few data regarding the operations of each of the Companies, collated from their tables so that the good points in each may be calmly weighed against the general average referred to.

The Alpha Company crushed, in about eight months, only 769·5 tons of quartz at a cost of Rs. 2,971-6-0 for raising and crushing, and obtained 91 oz. 12 dwts. 12 grains of gold, giving an average of 2·27 dwts. This work, according to the original estimate of 15 tons per diem, ought to have been done in two months and a half, reckoning 20 working days in the month.

The Prospecting Company crushed 99·85 tons, cost not given, in about eight months, and obtained 14 oz. 19 dwts. 19 grains, or an average of 3 dwts. At half a ton a day, the working-power of their stamper, this is a fair rate of work.

The Prince of Wales' Company crushed 322.66 tons in a little over six months, cost not stated, and obtained 164 oz. 17 dwts. 6 grains of gold, or an average of 10.5 dwts. Such work ought to have been done in a little more than a month with the Alpha machinery at the originally estimated rate.

The average cost of raising and crushing one ton of quartz by the Alpha Company was Rs. 2 and Rs. 1·85 respectively. Under the Prince of Wales' Company, the charge for mining was Rs. 4·15, and supposably the same rate for crushing as with the Alpha. In both cases, these rates are far too high. No returns have been supplied as to these charges with the Prospecting Company; but, from the experimental way in which the trials were made, the cost of raising was probably higher than in either of the other adventures, while that of crushing must have been proportionally low, considering that water is the motive-power employed.

In all cases, time has been the most expensive item; the charges for superintendence, pay of engine-drivers, permanent hands, and live-stock are far beyond any estimate which might have been proposed. For instance, in the account of expenditure of one Company, the charges for these amount to Rs. 3,942-12-10 in nine months, when the whole transaction, if properly organised and systematically carried on, even allowing for the delay consequent on putting the machinery in order, should have occupied, at the most, only half this time.

TABLE I.

Memo. of eight months' crushing, Alpha Gold Company Limited.

Month.	Quartz crushed.	Total yield.	Average yield.	Cost of raising.	Cost of crushing.	TOTAL.
1875.	Tons.	oz. dwts. grs.	oz. dwts. grs.	Rs. A. P.	Rs. A. P.	Rs. A. P.
September ...	99	8 12 0	0 1 17	172 0 0	126 1 6	298 1 6
October ...	40	8 0 0	0 4 0	176 9 6	170 15 6	347 9 0
November ... December ...	} 269	24 5 12	0 1 19	291 14 0	314 3 6	606 1 6

TABLE I,—continued.

Memo. of eight months' crushing, Alpha Gold Company Limited—continued.

Month.	Quartz crushed.	Total yield.	Average yield.	Cost of raising.	Cost of crushing.	TOTAL.
1876	Tons.	oz.dwts.grs.	oz.dwts.grs.	Rs. A. P.	Rs. A. P.	Rs. A. P.
January ...	175	22 14 0	0 2 14	293 4 6	269 0 6	562 5 0
February ...	170	17 12 10	0 2 1	328 8 0	368 3 0	696 11 0
March ...	20	3 19 15	0 4 0	182 5 0	116 3 0	298 8 0
November* ...	6½	6 9 10	0 19 22	97 2 0	65 0 0	162 2 0
TOTAL ...	769½	91 12 23	0 2 9	1,541 11 0	1,429 11 0	2,971 6 0

* Crushed at the works of the Prospecting Company.

TABLE II.

Memo. of crushings, Wynád Prospecting Company's works.

No. of trial.	Date of cleaning up.	Weight of stone crushed.	Yield of gold.	Rate per ton.	REMARKS.
	1876.	Cwt. qrs. lbs.	oz.dwts.grs.	oz.dwts.grs.	
1	5th October ...	44 0 0	0 9 17	0 4 10	
2	30th „ ...	420 0 0	2 17 21	0 2 18	
3	11th November ..	500 0 0	3 6 6	0 2 15	
5	29th „ ...	185 0 0	0 9 4	0 1 0	Not passed through amal- gamator.
6	4th December...	35 0 0	1 3 1	0 16 0	Picked stone; cost Rs. 15 per ton.
7	23rd „ ...	350 0 0	0 16 16	0 1 0	Not passed through amal- gamator.
8	28th „ ...	40 0 0	0 4 3	0 2 13	Stone rejected in trial No. 6.
	1877.				
9	6th January ...	175 0 0	0 8 13	0 1 0	Not passed through amal- gamator.
10	9th April ...	150 0 0	0 2 6	...	Hand-ground; burnt tail- ings.
11	21st August ...	140 0 0	3 15 0	...	Mr. Withers' work and selection.
12	25th September..	90 0 0	0 9 16	...	Tailings from No. 11 not burnt.
13	14th October ...	108 0 0	0 19 12	0 3 15	Jacob, carpenter's work; cost Rs. 7 per ton.
		1,997 0 0	14 19 19	0 3 0	

TABLE III.

Memo. of assays, Wynád Prospecting Company's works.

ASSAYS OF TAILINGS.					ASSAYS, VARIOUS.					
Weight.		Yield per ton.			REMARKS.	Weight.		Yield per ton.		REMARKS.
lbs.	oz.	dwt.	grs.		lbs.	oz.	dwt.	grs.		
22	0	6	7	Catch-pit, not burnt...	112	0	9	0	Average of 200-ton heap, English assay.	
12	0	3	21	Catch-pit, burnt ...	0	0	0	0		
10	0	4	20	Blanket, not burnt ...	10	0	9	8	Same stuff, Withers' assay.	
10	0	4	18	Buddle, burnt ...	10	0	2	9	Same stuff, Korumber's assay.	
40	0	11	16	Reverberatory furnace, hand-ground ...	5	1	3	0	Korumber's assay, Bear reef No. 2.	
112	0	3	8	Reverberatory furnace, not ground ...	5	0	10	0	Korumber's assay, Bear reef No. 1.	
112	0	6	3	Reverberatory furnace, hand-ground ...	18	0	2	12	Korumber's assay, sand from trials.	
1	0	1	7	Blanket tailings, English assay ...	9	2	5	0		
1	0	1	5	Catch-pit tailings, English assay ...	27	1	0	0		

TABLE IV.

Memo. of crushings, &c., Prince of Wales' Company Limited.

MONTH.	Quartz crushed.	Total yield of gold.	Average yield per ton.	Total cost of mining.	Average cost of mining 1 ton.	Average cost of crushing 1 ton.
	Tons.	oz. dwt. grs.	oz. dwt. grs.	Rs. A. P.	Rs. A. P.	Rs. A. P.
1877.						
August 17th ...	104·66	14 10 0	0 2 18·5	362 7 0	3 7 8	1 13 9*
September ...						
October 13th ...						
November ...						
Ditto ...	12·00	1 6 12	0 2 5	310 13 6	5 0 2	
December ...	50·00	29 9 0	0 11 19			
	50·00	41 6 0	0 16 12·25			
1878.				926 12 6	5 14 8	
January ...	104·00	77 9 18	0 14 21·6			
February 22nd...	2·00	0 16 0	0 8 0			
TOTAL ...	322·66	164 17 6	0 10 12	1,600 1 0	4 15 4	1 13 9

	oz.	Rs.	A.	P.
Specimens of gold in quartz sold in November, about ...	4·35	175	0	0
Ditto ditto December, „ ...	4	156	4	0
Ditto ditto Jany. & Feby. „ ...	23	920	0	0
Average price of gold from crushings, per ounce ...	...	41	10	8

* Presumed average, taken from Table I, of Alpha Company's results.

NOTES ON THE REPRESENTATIVES OF THE UPPER GONDWANA SERIES IN TRICHINOPOLY AND NELLORE-KISTNA DISTRICTS, BY R. BRUCE FOOTE, F.G.S., *Geological Survey of India.*

The following notes on the most southerly group as yet known of "plant beds" belonging to the upper division of the great Gondwana series, will be found to supplement very considerably the information given by Mr. H. F. Blanford about the "Ootatoor plant beds" in his very interesting Memoir "On the Cretaceous and other Rocks of the South Arcot and Trichinopoly Districts."

These beds, which crop out from below the western boundary of the main area of the cretaceous rocks, were worked out by Mr. H. F. Blanford when in charge of the Madras Party of the Geological Survey of India in the year 1858, 1859 and 1860. They were re-examined by me in the autumn of last year (1877), with the object of comparing them more closely with the various other groups of rocks of similar age which had since then been mapped during the progress of the Survey work northward, along the coast, into the Godavari valley.

The plant remains which characterise these beds, and the discovery of which first led to the separation of the "plant beds" from the overlying lithologically similar cretaceous series, were discovered by the late Mr. Charles Æ. Oldham, to the east of Ootatoor village, and were shortly afterwards recognised by Dr. Oldham, then Superintendent of the Geological Survey of India, as identical (in part) with the species occurring so numerously in the Rajmahal beds of Bengal, and with some of the fossil plants discovered in the oolitic beds of Cutch.

The Ootatoor plants were mostly referred to the genus *Palæozamia*, one of the Cycadeous family; and this is the only name mentioned by Mr. Blanford, presumably because none of the others had then been determined. The plants, though often so favourably fossilised that very delicate markings are perfectly preserved, are almost always very fragmentary in character—often mere shreds of the original plants.

The beds occur in six small detached patches, which all rest directly on the very uneven surface of the gneiss, and form a line running north-east-by-north to south-west-by-south, the extreme ends of which are fifteen miles apart.

As Mr. Blanford has given but little detailed information as to the variety of beds, the following sections will be found useful for comparison with other sections elsewhere. Lists of the fossils obtained by me will also be given further on.

I.—SECTIONS OF THE NAICOLUM PATCH.

Section No. 1 (in descending order).

15. Brown and purple sandstones with obscure plant remains.
14. Clays and shales, buff, light-brown
13. Ditto ditto, drab, white and buff } beds, rolling.
12. Sandy shale, hard, purple and brown.
11. Shales and clays, buff and whitish, with kunkur.
10. Shales, gritty, ferruginous.

9. Shales, gritty, with fine clay in nests.
 8. Ditto ditto, buff, drab and white, with reddish yellow, gritty partings.
 7. Ditto sandy, grey and drab, with clay galls.
 6. Ditto ditto, grey, white and buffy.
 5. Sandstones, micaceous, grey, reddish, thick-bedded, dip 10° to 12° east.
 4. Shales sandy, white drab, grey.
 3. Ditto ditto, buff, drab, red, dip 45° north-east.
 2. Gritty beds, with much kunkur.
 1. Silt, clayey, mottled white and red.
- Gneiss.

This section extends over a distance of 900 paces along the lane running east from Naicolum village.

Section No. 2.

10. Shales and clays, micaceous, grey, white, drab, pale buff, brown, with plant remains.
 9. Shales, gritty, brown.
 8. Ditto, micaceous, drab.
 7. Clays, white, grey.
 6. Grits, micaceous.
 5. Shales, gritty, micaceous, with kunkur.
 - Gap in section.
 4. Grit, hard, grey, calcareous.
 3. Shales, grey and white.
 2. Grit, brown.
 1. Boulder bed.
- Gneiss.

This section is seen in the small rain gully running north-east from the extreme southernmost point of this plant-bed area. The few plant remains found in this section were all obtained in No. 10. Amongst these were a fairly well preserved specimen of part of a frond very nearly allied to (if not identical with) *Otozamites abbreviatus* and a pinnule of *Ptilophyllum acutifolium*. The other plant remains were undeterminable, grassy-looking stalks. Mr. H. F. Blanford describes the plant beds here as abounding in *Zamia*, so probably he had the good luck to hit upon particular beds rich in fossils which escaped me, though I searched very carefully for them. His description gives no clue as to what part of the series he found the fossils in.

From section No. 1, I obtained nothing recognisable on cursory examination, and was prevented by bad weather from making a closer search.

II.—SECTIONS IN THE OOTATOOR-TERANY PATCH.

Both ends of this patch of the plant beds proved themselves rich in fossil remains, representing a considerable number of genera characteristic of the Rajmahal flora. The following section No. 3 gives a good idea of the succession of beds in the southern part of the patch :

Section No. 3.

23. Gritty sandstones, grey, massive.
22. Ditto, coarse, ferruginous, purple to brown, rolling.

21. Gritty sandstones, and shales, grey, alternating.
20. Ditto, buff and drab, false bedded.
19. Ditto, grey and whitish grey, flaggy.
18. Shales, gritty, grey, drab.
17. Gritty sandstones, coarse, ferruginous.
16. Ditto, buff, false bedded.
15. Ditto, grey, drab.
14. Shales, sandy, drab.
13. Ditto, white, grey, buffy.
12. Gritty sandstones, brown, flaggy, with a few pebbles.
11. Ditto, false bedded.
10. Conglomerates and sandstone (local), with red clay in galls and lenticular patches.
9. Pebble and boulder bed (local).
8. Sandstone, gritty, buff, brown.
7. Ditto, ferruginous.
- Small fault.
6. Grit, shaley, drab.
5. Conglomerate, gritty, ferruginous, enclosing gneiss pebbles.
4. Grit, fine light-colored, enclosing boulders.
3. Ditto, coarse, ferruginous.
2. Ditto, fine bedded, shaley, brown, buff, pinkish.
1. Boulder bed.
- Gneiss.

The direction of this section is, roughly speaking, from west-south-west to east-north-east, and the length about one-third of a mile. The dip is easterly, but shifts several points northward and southward with the rolling of the beds. The average dip is from 12° to 15° but varies a good deal in parts. The plant remains were mostly obtained from beds Nos. 13 and 14, but a few also from a thin bed of clayey red sandstone, a little distance south of the section locally underlying No. 11.

The fossils obtained at the Terany end of this patch of plant beds were found in the materials excavated in sinking two new *bowries* in the paddy flat immediately east of the villages. As the beds are nearly horizontal, their base is obscured by the water in the wells; but they are probably low down in the series, as they lie close to the gneiss boundary.

The fossiliferous rock is a fine shaley micaceous sandstone of deep buff colour, and unfortunately rather friable, so that the impressions of the plants are very easily effaced. They will be enumerated further on.

III.—THE (KAURAY) KÁRI PATCH.

A good section of the western end of this patch is formed by a nullah which drains into the tank north-east of Terany.

Section No. 4.

16. Grit, purple (overlaps on to the gneiss).
15. Shales, drab and buff and grey, mottled.
14. Ditto, sandy, buff, with large concretions.

13. Grit, with band of calcareous concretions, some quite gritty.
 12. Shales, grey and buff.
 11. Ditto, buff, reddish, with gritty partings, locally.
 10. Grit, hard, purple, brown.
 9. Calcareous concretions, band of, with much kunkur.
 8. Shales, sandy or clayey, buff, yellow, grey, white.
 7. Grit, hard, purple, orange.
 6. Shales, clayey, grey, white, with bands of ferruginous concretions.
 5. Grit, hard, purple, brown.
 4. Ditto, mottled (with gneiss pebbles).
 3. Ditto hard, thin-bedded, orange and purple.
 2. Shales, clayey and sandy, grey, mottled, with sandstone partings.
 1. Grit, semi-compact, mottled, purple, buff, orange, grey and white, with fragments of felspar, ferruginous concretions, and much kunkur.
- Gneiss.

The succession of the beds in the upper or northern part of the section is obscure, but they seem to succeed each other regularly, and to abut against the gneiss, which here rises in a steep bank. The mineral character of the different beds changes so rapidly, that it is very difficult to trace them with certainty where the sections are not very clear and distinct.

A little to the east of the above section the basement bed is of a bright blood-red with grey and white specklings, and the representative of No. 3 on rich red or purple grit. The boulder bed, so characteristic elsewhere, does not occur in this section.

Fossils are not numerous in this part of the Kari patch; the only one found by me was a rather fine frond of *Otozamites*, procured from the buff shale bed No. 8.

IV.—THE COODICAUD-KULLPAUDY PATCH.

The greatest development of the boulder bed at base of the plant series is to be seen to the north-west of Coodicaud, and here, as near Ootatoor, the included boulders are greatly decomposed. The spaces between the boulders are occupied by a fine silt of buff or brownish yellow colour. The following section of the lower part of the series was observed in a rain gully east of Iyalur (Aiyalur):

Section No. 5.

6. Grit, greenish, yellow.
5. Ditto, ditto and drab.
4. Limestone, coarse concretionary, dull-brown, with badly preserved traces of plants.
3. Grit, buff.
2. Grit, silty, buff, with much kunkur.
1. Boulder bed, with buff silt.

The impressions of plants in the limestone are not recognisable. The beds roll about at low angles, but have a general low dip south-eastward. The upper bed is covered by cotton soil, which extends for a considerable distance eastward. Further to the north-east the plant series is more fully exposed in numerous deep rain gullies, and shows, as pointed out by Mr. Blanford, "alternations of micaceous shales and grey sandstones and grits with great gritty calcareous concretions."

The dip is eastward or north-eastward at angles from 8° or 10° up to 15° and 20° . Plant remains are rare; Mr. Blanford failed to find any, but Mr. Oldham was more fortunate; and I too succeeded in finding some in two beds. In the first case, the matrix was a rather coarse friable micaceous shale, and the remains neither characteristic nor preservable. In the second case, a fine-grained, rather soft, buffy-brown, sandy shale near the base of the series yielded well preserved, but fragmentary, remains of *Pterophyllum* sp., of *Philophyllum cutchense*? and *Angiopteridium spathulatum*, besides a Cycadeous (?), fruit and stalk-like fragments.

V.—THE DISPUTED BEDS AT MARAVATUR.

According to Mr. H. F. Blanford's views, no true plant beds occur northward of the Coodicaud-Kullpaudy patch just described, but, according to Dr. Oldham's views, another patch of them occurs about a mile to the north of Maravatur (Moraviatoor of Sheet 79). Mr. H. F. Blanford contended strongly that the latter beds were really of cretaceous age, though petrologically very like the true plant beds further south; and based his contention mainly on the fact that he could "not find any remains of plants," while the stratigraphical relations of the disputed beds and the overlying Ootatoor beds appeared to indicate conformity and true sequence. Dr. Oldham, on the other hand, insisted that he had discovered true Rajmahal plants in these disputed beds in 1859, and again when he revisited the place in 1861.

The results I obtained after a most careful examination of this disputed patch of ground compel me to adhere to Dr. Oldham's view, that it is an extension of the true plant beds. Plant remains do unquestionably occur in several of the beds near the gneiss, together with impressions and casts of a small bivalve shell. The plant remains are, it is true, very ill preserved and quite fragmentary, but patient searching yielded a number of specimens which admit of approximate determination; and these represent some of the commonest forms in the undisputed plant beds of Terany and Ootatoor. Had I not found these plant remains, I should have sided with Mr. Blanford, for the stratigraphical evidence of a break is wanting.

The fossil plants that are recognisable in the specimens I obtained are various fronds of *Angiopteridium*, a fragment of a fern very near to *Sphenopteris*, and fragments of *Philophyllum*, *Macrotaeniopteris ovata* (?), and *Dictyozamites*. I have sent up 19 specimens of plants in all to our Museum from Maravatur, and should have sent many more but that they had crumbled into dust, owing to the cases they were packed in having, together with much of my most valuable luggage, as despatch-box, book-box, gun-case, &c., been soaked in a tank for some while through the cleverness of a cartman. As will be readily understood, when the identity of the source of the materials of which both the plant beds and overlying cretaceous rocks are formed is considered, there is a very strong petrological resemblance between many of the beds in both formations. There is quite as great a variety in mineral character and colour among the members of the plant-bearing series as in a similar thickness of deposits in the cretaceous group. To my mind, they

are by no means so monotonous in composition or colour, as compared to the cretaceous rocks, as Mr. Blanford's description would lead one to believe.¹

The position occupied by the several patches of Rajmahal beds now described is quite analogous to that of the various other patches occupied by them along the coast as far north as the neighbourhood of Ellore in the Godavari district. There is also very strong resemblance in the petrological character of these beds with many of those occurring in the Chingleput, Nellore, and Kistna districts, as will be pointed out further on. Many beds in those districts are unquestionably of marine origin, as proved by the fossils they enclose; and such beds enclose also numerous plant remains in no wise different in kind, or in state of preservation, from those not associated with marine remains. This throws a doubt on the assumption, that all the Rajmahal beds in Trichinopoly district are of fresh-water origin. Except the negative evidence from the absence of marine fossils from such beds, there is no ground for supposing such beds to be of fresh-water origin; and this latter supposition requires a total rearrangement of the geographical conditions which may, from recent analogy, be supposed to have existed at that period. When Mr. Blanford wrote his Memoir, it is true none of these other Rajmahal formations were known or suspected to be of marine origin; his deduction therefore of their fresh-water origin was natural.

The discovery of a marine fauna in the southern representatives of the Upper Gondwana series was first made by myself when surveying the Sripermatur area west of Madras in 1863. From the nature of the plants there discovered in the same beds of (white or grey) shales with the marine remains, no doubt could remain of their formation being truly of Rajmahal age. Since then still more strikingly marine beds have been discovered containing Rajmahal plants, *e. g.*, the Ragavapuram shales in the Godavari district by Mr. King, Deputy Superintendent, Geological Survey of India (in 1874); also the Vemávaram shales in Nellore district (by myself in 1875); and the Budáváda shaley calcareous grits also in Nellore district (found by me in 1876). The northerly extensions of the two latter formations into the Kistna (Guntoor) district are also of marine origin, and so, too, are the plant-bearing beds further south in the Nellore district at and around Kandallur.

The nature of the small bivalves found in the "disputed beds" at Maravatur has not yet been determined critically; but they look to me, if I may trust my memory to that extent, very much like some minute shells that I found in some of the plant beds north and south of Kandallur, associated with other unquestionably marine shells.

In his interesting paper "On the Age and Correlation of the Plant-bearing Series of India," read by Mr. H. F. Blanford before the Geological Society (of London),² he speaks of "beds with marine fossils intercalated with them" (the plant beds); this is not correct, for there is no separation of the beds. Where the marine fossils occur, plant remains occur also, and often in the same band specimen; and these plant remains are precisely in the same condition, and fossilised

¹ Memoirs, G. S. I., vol. iv, p. 42.

² Quar. Journ. Geol. Soc., vol. XXXI, p. 519, 1875.

in the same way, as those occurring in other shale beds, where marine fossils are not found. This association of the plant and animal remains occurs also, and very markedly, in the shaley beds at Vemávaram (in Nellore district), and further north in the Kistna district.

I confess it appears to me to be unnecessary to imagine that any of the beds are of fresh-water origin, simply because of the absence of marine fossils from some of them, when they abound in other beds intimately associated with, and perfectly conformable to, the former. A change of level and of other geographical circumstances, so great as to replace the sea by a lake, or large river, or *vice versa*, is one of such magnitude, that it would surely produce some stratigraphical discordance of corresponding import. No such discordance is traceable in any of the numerous patches of Upper Gondwana plant beds that I have now seen. The absence of marine fossils from some of the beds should therefore, I submit, be explained in some other way.

For the sake of comparison, I give below several sections from the more northerly patches of Upper Gondwana rocks. The first of these occurs in the banks of the Naggery river at Chittapuram, a little below the junction with the Tritany river, in North Arcot district. The same beds occur in both banks, but they are best seen in the right, or south, bank. The succession of beds in downward succession is the following:—

8. Laterite and quartzite shingle bed.
7. Quartzite shingle, with sandy matrix.
6. Gritty friable sandstone with shaley and kunkury layers; the gritty parts much false-bedded.
5. Quartzite shingle, with sandy matrix.
4. Friable sandstones, with plant remains.
3. Coarse shingle, matrix of sandy clay.
2. Clays, light brown grit, with bands of sandstone and plant remains.
1. Boulder bed, resting on the gneiss which shows a little to the west.

The plant remains were obtained from the corresponding beds on the north bank of the river. They consisted of a small, but broad, leaf, closely resembling *Macroteniopteris ovata*, from No. 4 of which several specimens were found, and of fragments of fronds of *Dictyozamites* and *Ptilophyllum*, from No. 2.

The sections near Sripermatūr are such very shallow ones, that they afford but little material for comparison. The best perhaps is that seen in the Kam-bam Kal (a channel feeding the great Sripermatūr tank), about half a mile west of the Engineer's bungalow. The beds exposed are—

5. Lateritic sands, with quartzite implements.
4. Shales, pure white, compact—the “plant beds.”
3. Grits, yellowish, coarse, with shaley partings, much false-bedded, very friable.
2. Shales, sandy, micaceous.
1. Sandstones, gritty, white and greenish, grey, friable.

The last section that I will quote from the Sripermatūr area occurs at Vatambakam (Vantambanum of Sheet 78) in the southern part of the area, where a

small headland some 30 feet high juts out from below the Oragidam laterite plateau. The beds here seen are—

13. Laterite gravel, with quartzite pebbles.
12. Clay, white sandy, with concretionary lateritic ironstone.
11. Grit, friable, coarse brown, buff and whitish, with shale and sandstone partings, passing down into—
10. Sandstone, brown and reddish-brown, compact, lateritic and shaley.
9. Sandstone, buff, very fissile and shaley.
8. Clay, sandy, white and pale buff, rather friable with plant remains.
7. Sandstones, shaley, purple and buff with clayey partings.
6. Shale, sandy (local).
5. Clay, white.
4. Sandstone, shaley, purple at top, buff below.
3. Clay white.
2. Sandstones, thin-bedded, buff, more gritty and purple at top.
1. Shales, sandy, whitish, friable.

The plant remains in No. 8 are numerous and well preserved, but very difficult to secure, owing to the very friable nature of the matrix. Among the fossils were two or three species of *Ptilophyllum* and *Angiopteridium*.

There is nothing in the Trichinopoly plant beds that resembles the hard compact shale variety which occurs at several places in the Sripermatūr area. In texture and lustre this shale is sometimes almost porcellanic, and when fossiliferous contains the best preserved remains found. A similar variety is common at Vemāvaram in the north-eastern corner of Nellore district. Here it is, however, never quite so hard as the hardest forms seen near Sripermatūr, but, like them, shows the fossils enclosed in a high state of preservation.

Most of the fossils found in the Sripermatūr area and at Vemāvaram are covered by a thin film of colour, either red or purple, more rarely brown or black, which does not extend to the surrounding shale or sandstone, so that the organism is strikingly set off. It is very rare for the colour to extend beyond the limits of the organism. This colouring is much less frequent in the Trichinopoly specimens. The vegetable fossils from all the Upper Gondwana formations on the Coromandel coast agree in being very fragmentary, however well preserved they may be in other respects. They were evidently swept out to sea in some condition, and speedily imbedded before decay attacked them.

The Trichinopoly patches show many fewer argillaceous beds than do the more northern ones, especially those in the neighbourhood of Madras and of Guntoor; this may be due in great measure to the different mineral character of the mass of the gneissic rocks which yielded the materials of which these younger rocks were built up. Both opposite the Madras and Guntoor Upper Gondwana areas, coarse, highly felspathic granitoid gneiss constitutes the main mass of the country over many hundred square miles, while the bulk of the gneissic rocks forming the Patchamallays, the high lands which yielded great part of the materials of the Trichinopoly beds, are pre-eminently silicious and ferruginous.

Of the sections to be seen in the patches of Upper Gondwana rocks occurring on the borders of the Nellore and Kistna districts, two only are worth special notice; for, as a rule, the beds are so little exposed, that it is impossible to trace their succession with any certainty. This is due in part to the very slight elevation of the area they occupy, much of it being hardly raised above the general level of the band of coast alluvium, in part also to the very great thickness of cotton soil which extends far and wide over all the older formations. The two best sections are the Vemávaram section (only 8 miles from the coast and 12 miles north-east-by-north of Ongole) and the Boodavadah section, 11 miles to the north of the former. In neither section are the uppermost beds seen, being obscured by the coast alluvium and superincumbent cotton soil. The exposed beds are, in downward succession,—

9. Shales, purple.
8. Do., buffy.
7. Do., softish, brown, white and purple.
6. Do., hard, with red and brown sandstone partings.
5. Do., do., partly flaggy, variegated.
4. Sandstone, parting.
3. Shales, thin, flaggy, buff and white, rather hard, "fish bed."
2. Do., sandy, mottled.
1. Sandstones, shaley, buffy in colour.

The base of the section is also obscured by cotton soil, but about a mile to the west, softish gritty sandstones are seen resting on a hummocky granite gneiss, analogous to parts of the boulder beds forming the base of the Ootatoor plant beds in so many places. Some of these gritty sandstone beds abound in fragmentary plant remains, impressed in red colour on the friable surface. Among the impressions many are not determinable, but perfectly recognizable fragments of *Dictyozamites* (a small form) are very numerous amongst the others. A series of these was sent up in 1875, but from the great friability of the sandstones it is very possible they did not bear the journey. Except in the coarser character of the rock, the general appearance and mode of occurrence of the fossils from these bottom sandstones are a good deal like those of the fossils found at Terany in Trichinopoly district.

The second section in the Nellore-Kistna ground, to be quoted for comparison with the Ootatoor plant beds, occurs at Budaváda in Nellore district, 25 miles north-north-east of Ongole, and $3\frac{1}{2}$ miles west-north-west of the travellers' bungalow at Inkolu on the old Madras-Guntoor road. This section seems to take in the whole of the Upper Gondwanas in this region, but is not by any means as distinct as might be wished, and I offer it as an approximation to the truth and as liable to possible modification hereafter. The section is based upon the results of examination of a series of wells, supplemented by a few poor outcrops and small stone pits. The obscurity is due to the great thickness of cotton soil over the eastern half of the section.

The section which extends from half a mile west of Budaváda (Boodhawadah of Sheet 76) runs due east for the first half of its length, and then turns north-east up to the village of Pávulur, the total length being $2\frac{1}{2}$ miles. The series of beds

here seen, and which I divide into three groups, is thus arranged in downward succession :—

PAVULUR GROUP ...	{	9. Sandstones, friable, coarse reddish-brown.
		8. Do., hard, greenish-black, calcareous, slightly shelly weathers grey or brown.
		7. Do., friable, drab, pale brown.
VEMAVARAM GROUP ...		6. Shales, various, hard and soft, mottled in parts, generally light grey in colour.
BUDAVADA GROUP ...	{	5. Sandstones, gritty, calcareous and full of shells, rather hard and, tough when fresh.
		4. Do., shaley, friable, drab, buffy.
		3. Do., hard, brown, alternating several times with shaley beds.
		2. Do., massive, hard, brown.
		1. Do., pebbly, outcrop much weathered.
		Gneiss

The general dip is easterly, at varying and generally very low angles. Beds Nos. 4, 5, 6 and 8 contain marine shells; Nos. 5 and 6 contain plant remains as well, and No. 9 plant remains only.

The Vemávaram shales, I believe to be represented by the shales No. 6, and these latter do not differ much, as far as seen, from many of the softer beds in the Vemávaram section, and they resemble many of the shales in the Ootatoor group. The shelly sandstones, No. 5, are utterly unlike anything as yet known in any of the other Rajmahal areas throughout India.

Whether the three groups into which the plant beds of the Nellore-Kistna area here show themselves to be naturally divisible can be correlated with the three groups Mr. King has established for the Upper Gondwanas of the Godavari district remains to be seen, when the flora and fauna of the more northerly series shall have been worked out. I am inclined to doubt it at present. Of the petrological agreements there can of course be no doubt, but the palaeontological evidence of the most important plants, and of the very interesting crustacean of the genus *Eryon* which I discovered at Vemávaram, appear to me to indicate that the Vemávaram group is of the same age, and not newer than Mr. King's Golapilly sandstones in the Godavari district, which Dr. Feistmantel regards as a true Rajmahal formation. I look upon the Vemávaram group as the true marine representative of the Rajmahal formation proper. My reasons for so thinking I will not discuss here at length, but reserve them for a fuller account of the Nellore-Kistna Upper Gondwana groups, which I am now engaged upon.

None of the "plant bed" areas of the Madras Coast has been exhaustively searched, and further research may yet add largely to their floras and faunas; but such further research is not likely to be undertaken by members of the Geological Survey, at any rate for a very long time. The collections we now possess must therefore for the present be assumed to represent fairly the real contents of the several groups of beds. By means of the rough lists of fossil plants from the Ootatoor group of patches severally, the Sripermatour area generally, and

Vemávaram and Budavada severally, which I give below, the respective floras may be compared roughly.

A few facts concerning the distribution of the leading plants which the mere lists do not show may be pointed out in conclusion of my notes. *Dictyozamites* is a genus very rarely found in the Ootatoor group of beds; it is rather more frequently met with in the Sripermatur area, but by no means a common plant there; at Vemávaram, on the contrary, it is one of the most numerous, and shows considerable varieties of form and size. *Angiopteridium spathulatum* is very common at Terany, and occurs in most of the other Ootatoor localities; it is rather uncommon in the Sripermatur area and one of the rarest forms seen at Vemávaram. The form most peculiar to the Sripermatur group, where it occurs frequently, is one I take to be a Conifer hitherto undescribed. This form, which has some resemblance in the arrangements of the leaflets on the stalk to *Taxites tenerimus*, Feistmantel, figured in the Flora of the Jabalpur Group, but greatly exceeds that species in size, is very rare at Vemávaram, and was not found at all in any beds of the Ootatoor area. *Echinostrobus rajmahalensis* is numerous and remarkably well developed at Vemávaram; it is rare in the Sripermatur area, and absent from the Ootatoor plant beds. Similarly the genus *Pterophyllum* is much better represented both in number of species and specimens at Vemávaram, than either at Sripermatur or in the Ootatoor area.

Dr. Feistmantel considers the Sripermatur group and Trichinopoly or Ootatoor plant beds as equivalents of Mr. King's Ragavapuram beds (Godavari district), a view in which I am quite prepared to agree with him. As already mentioned with reference to my Vemávaram crustacean, which he described as *Eryon* Comp. *Barrovensis*, he has, owing to some unfortunate confusion of the collections, looked upon the Sripermatur and Vemávaram fossils as both coming from the vicinity of Madras, though in reality belonging to localities more than 200 miles apart. When he comes to separate them, I quite expect he will see the necessity of looking upon the Vemávaram beds as rather older than both the Sripermatur and Ootatoor plant beds.

The following lists give the fossils collected by me from the several patches of the Ootatoor plant beds; their determination is of course only preliminary, the final one having yet to be made by Dr. Feistmantel at the Museum in Calcutta, where they can be compared with the type specimens of all the Upper Gondwana floras at present known. The several localities are arranged in their geographical sequence from south to north. In drawing up and correcting these lists, I have of course availed myself as much as possible of Dr. Feistmantel's very valuable monographs.

1. NAICOLUM.

Ptilophyllum acutifolium.

Otozamites abbreviatus?

Branching leaf-like stalk.

Grass-like branching (dichotomous) leaflets, very delicate.

Stalk with central groove.

2. OOTATOOR.

*Cyclopteris?**Alethopteris indica.**Angiopteridium spathulatum.**Macrotæniopteris ovata?**Zamites?**Ptilophyllum acutifolium.**Pt. cutchense?**Otozamites?**Palissya*, sp.

Seeds or small fruits, numerous; Cycadeous?

Stalk ribbed.

3. TERANY.

Sphenopteris, sp.*Alethopteris indica.**Angiopteridium spathulatum.**Macrotæniopteris*, sp.*M. ovata?**Pterophyllum*, sp.*Pt. distans?**Ptilophyllum acutifolium.**Dictyozamites indicus.**Otozamites*, sp.*Pallissya indica.**Cheirolepis?*

Seeds or small fruits.

Stalk-like fragments of various shapes.

4. KARI (KAURAY) SOUTH PATCH.

Otozamites, sp. ? *abbreviatus?*

5. KUDIKAD (COODICAUD)-KULLPAUDY PATCH.

*Angiopteridium spathulatum.**Pterophyllum*, sp.*Ptilophyllum cutchense?*

Fruit or seed, cycadeous?

Ribbed stalk of—?

6. MARAVATUR.

Sphenopteris, sp.*Angiopteridium spathulatum.**Macrotæniopteris ovata?**Ptilophyllum acutifolium.**Dictyozamites indicus.*

Lists of the fossil plants from the Sripermatur and Vemávaram groups and from Budaváda are added, to assist in comparing all the groups.

SRIPERMATUR GROUP.

Sphenopteris, sp.*Pecopteris?**Angiopteridium spathulatum.*

Macrotæniopteris, sp.
Pterophyllum, sp.
Ptilophyllum acutifolium.
Pt. cutchense?
Otozamites, sp.
Dictyozamites indicus.
Palissya, sp.
Echinostrobus rajmahalensis.
 Grassy stalks.
 Scales or bracts. ? *Araucarites*.
 Seed vessels.
 Coniferous leaves, undetermined.

VEMAVARAM GROUP.

Sphenopteris, sp.
Dicksonia, sp.
Cyclopteris? sp.
Alethopteris indica.
Angiopteridium spathulatum.
Macrotæniopteris ovata.
M. sp.
Pterophyllum distans?
Pt. sp.
Pt. fissum.
Zamites proximus.
Ptilophyllum acutifolium.
Pt. cutchense.
Otozamites, sp.
Dictyozamites indicus.
Palissya indica.
Cheirolepis?
Echinostrobus rajmahalensis.
Araucarites, sp. (? *macropterus*.)
Cunninghamites dubiosus?
 Coniferous leaves, undetermined.

The plant remains obtained from the shelly grit No. 5 at Budaváda were:—

Angiopteridium spathulatum.
Ptilophyllum acutifolium.
Otozamites abbreviatus?
Dictyozamites indicus.

The shales No. 6, the apparent equivalents of the Vemávaram shales, yielded:—

Pterophyllum sp.
Ptilophyllum acutifolium.
Pt. cutchense.
Palissya indica?

The list of Vemávaram fossils was drawn up from only a small part of my collections, and is therefore far from complete, but, as it is, it shows a far greater wealth of form than appears in any of the other localities.

SENARMONTITE FROM SARAWAK.

When recently arranging the Indian and foreign ores of antimony in the Geological Museum, I found, amongst those from Sarawak, in Borneo, which consist mainly of the sulphide and native antimony, a specimen which contains more than one oxide. It is about half a pound in weight, and consists of native antimony with *stibnite*, greyish-white and grey filamentous tufts, which appear to be *volentinite*, but which are only distinctly visible under the lens, and cannot be isolated for examination, *senarmontite* and *cervantite*. The first four are rather intimately mixed up, but small fragments of the *senarmontite* are separable, sufficiently large for satisfactory determination. It occurs both massive and in crystals, which are unmodified *octohedrons*: the larger of these are about a fiftieth of an inch in diameter; the hardness is about 2, the colour of the massive portion is white and greyish, with resinous lustre; the crystals are grey and translucent, with sub-adamantine lustre on the faces. On charcoal the mineral gives an abundant coating of antimonious oxide; it dissolves in hydrochloric acid, the solution yielding a white precipitate with water and an orange-red one with hydrosulphuric acid. I am not aware that *senarmontite* has been previously noticed from Sarawak, and hence put the above observation on record.

F. R. MALLET.

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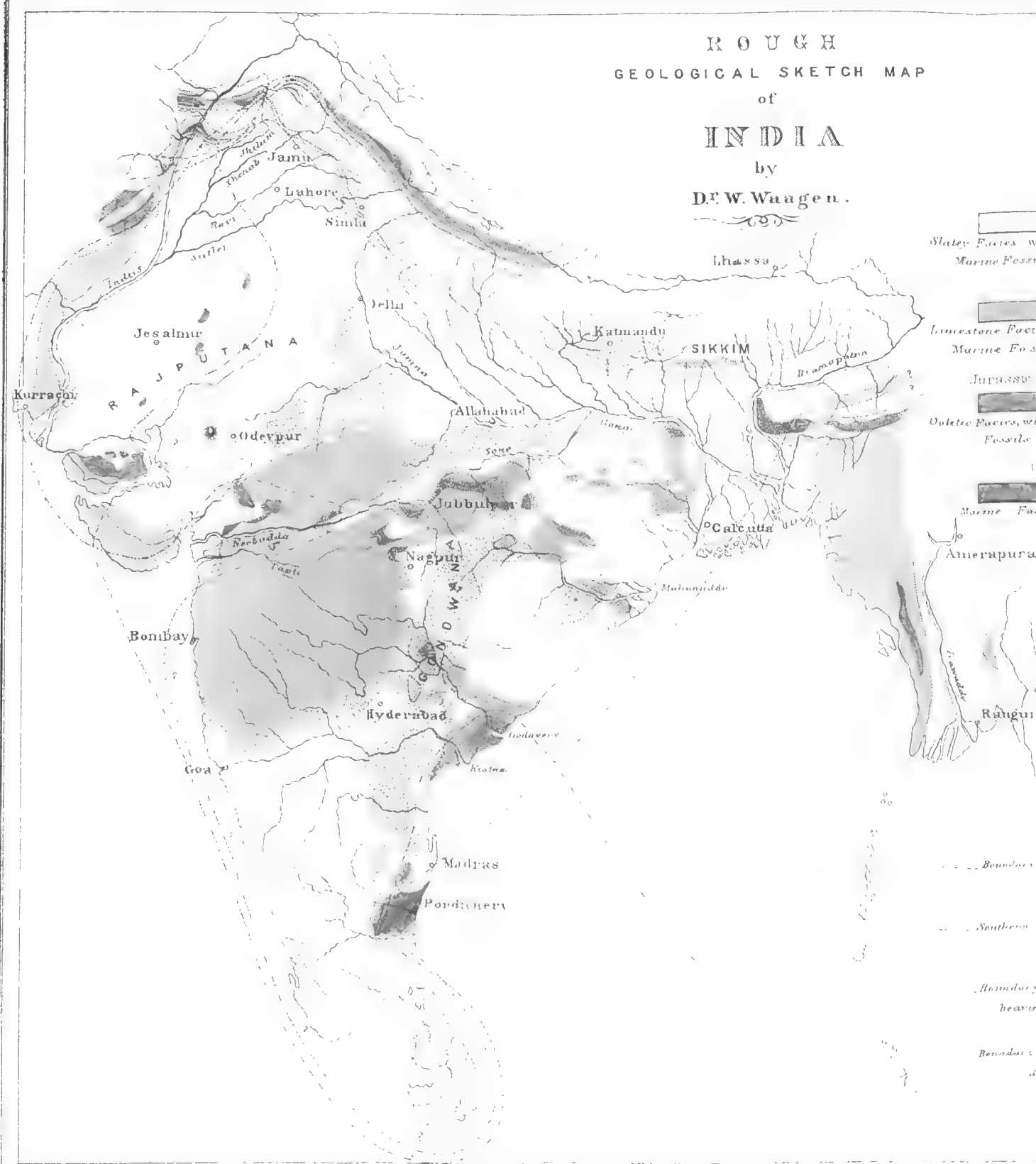
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July 15th, 1878.

ROUGH
GEOLOGICAL SKETCH MAP
of
INDIA
by
DR. W. Waagen.



Description of Colours.

	Crystalline.		Deccan Trap.
	Palaeozoic		Nummulitic Strata.
	Slaty Facies with Marine Fossils.		Sandstone Facies without Fossils.
	Triassic.		(Eocene and Oligocene)
	Limestone Facies with Marine Fossils.		Sandstone Facies with Plants without Marine Fossils.
	Jurassic and Lower Cretaceous.		Siwalik
	Oolitic Facies, with Marine Fossils.		(Miocene and Pliocene)
	Upper Cretaceous.		Alluvium
	Marine Facies.		(of the Ganges and Brahmaputra)
	Freshwater Facies.		

Explanation of Symbols.

- Boundary between Slaty and Sandstone Facies of the Palaeozoic Formations.
- Southern Boundary of Marine strata of the Trias Formations.
- Boundary between the strata with Marine Fossils and the plant-bearing sandstone of the Jurassic and Lower Cretaceous.
- Boundary between the Marine strata and the Freshwater deposits of the upper Cretaceous.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.]

1878.

[November.

ON THE GEOGRAPHICAL DISTRIBUTION OF FOSSIL ORGANISMS IN INDIA, BY DR. W.
WAAGEN.

(*With a Map.*).

Read at the meeting of the Mathematical and Natural Science Section of the Imperial Academy of Sciences, Vienna, 1st December 1877.

Translated by R. BRUCE FOOTE, F.G.S., Geological Survey of India.

Although many facts relating to the geology of India have been made public through the labours of the Geological Survey of India and the activity of many non-professional geologists, there has been no work by which it was possible to obtain a view of what was known up to date, and the absence of any even approximately accurate general map has been a very sensible want in Indian geological literature. Greenough's map was utterly useless, because perfectly untrustworthy; India, as shown in Marcou's geological map of the world, is on much too small a scale to be useful in more advanced discussions. It cannot be my intention to remove this inconvenience thoroughly; to do that lies solely in

Note.—The Geological Survey of India has been specially unfortunate in prematurely losing the services of the two accomplished palæontologists who successively undertook the highest branch of its investigations; as palæontological researches, more than any others perhaps, demand a close acquaintance with an immense array of details, and the patient discussion of these from various points of view that are still, more or less, debatable. We are therefore to be congratulated that Dr. Waagen has been able to bring together his reflections upon the information he collected while his health permitted him to work in this country. This most recent essay upon the primitive geography of India by a palæontological expert, is re-produced in our Records for the benefit of students who may not have access to the original paper. There are, as the author himself surmises, numerous small mistakes of geographical detail, etc.; but as they do not affect the general purpose of the paper, they have been left uncorrected.—H. B. MEDLICOTT.

the power of the Director of the Geological Survey of India, for he alone has at his command the materials necessary for the construction of a detailed map on a larger scale. The geology of India shows, however, so many most interesting facts that can only be represented on a cartographic basis, that I have no hesitation in laying down on a small sketch map, even at the risk of many inaccuracies in detail, what are at present approximately settled facts. My sole object now is to show in bold outlines the geographical distribution of the several formations in India, and for that purpose the annexed map is amply sufficient. As the title of this essay already shows, the geological map is not the object in view; it is intended only as a basis for the discussion which deals with the geographical distribution of fossil organisms. It is only by the absolute want of any general geological map of India that I am forced to compile one from existing sources and my own experiences, but for this I should have greatly preferred availing myself of what already existed.¹

The peculiarity of the subject demands, besides, a peculiarity in the representation such as has till now been but rarely applied to geological maps. I found myself compelled not only to separate the formations according to their boundaries, but also to represent clearly the differences of facies in the formations themselves, so that the first glance at the map should give a general view of the distribution of the facies. It will be only by this method of representation that one can follow with ease the conclusions which I feel myself justified in drawing from the geographical distribution of the fossils.

It has long been known that the different formations in various parts of India have been developed according to very different types, and this diversity attained often such a magnitude that it appeared almost impossible to harmonize the succession of formations in one region with that obtaining in another. It has become customary in India to recognize (following Blanford) two chief types of development which were designated as the Himalayan and Peninsular types: the first of these was compared with the Alpine type of the European scale of formations, the second with the extra-Alpine type, without entering into other and more special analogies. But several writers in India² had already pointed out that probably the greater part of the plant-beds of the Indian Peninsula were of fresh-

¹ I base my little map chiefly on the surveys and reports of my former colleagues, the members of the Geological Survey of India, but in several cases I could only give the boundaries of formations approximately, as the reports are frequently unaccompanied by maps, *e. g.*, in the region south of the great basaltic districts, in the lower course of the Godavari, in Rajputana, and in Sindh, &c. (Vols XII and XIII of the Memoirs Geological Survey of India were not available to me when preparing the map). For small parts of Behar, the Central Provinces and Rajputana the representation is based only upon probabilities, as both reports and maps are wanting in these cases. I have no hesitation in thus drawing attention to the deficiencies of my map, for one reason that the object of the present publication does not centre in the map, for another, that the inaccuracies at the points indicated are probably not of a character to alter materially the general view of the geological structure of India which is the aim of the map.

² Lately by H. F. Blanford: *Quart. Journ. Geol. Soc., Lond.*, 1875, and before him by T. Oldham, W. T. Blanford, and several others.

water origin. This, however, does away with all analogy with the European extra-Alpine formations; and a much more important distinction is established between the two chief types of development of the Indian formations than is the difference between Alpine and extra-Alpine formations, it is the distinction between deposits of the open sea and those of an inland basin. Neither does the geographical distribution of the two types fit the geographical regions of the Himalaya and the Indian Peninsula, but is, as I shall endeavour to show, a totally different one.

Although the crystalline rocks are not of the same great importance to the palæontologist, as such, that they are to the geologist, they yet demand close consideration here, as they form the foundation of the sedimentary rocks, their geographical distribution in earlier ages having determined in great measure the geographical distribution of the younger rocks; moreover, they reveal themselves as metamorphosed sedimentary formations.

If we now regard India with reference to these oldest rocks, it appears that the base of the peninsula proper consists throughout of crystalline rocks, supporting the sedimentary rocks in small separate basins, and only in the western parts completely covered, over large areas, by eruptive formations. To the north-west the crystalline rocks of the Indian peninsula are bounded by the range of the Arvali mountains, to the west of which only younger sedimentary formations appear, extending far away into Biluchistan and Persia. In Kattywar also is a small mountain mass of crystalline rocks which may perhaps join on to the larger Aravali range, as I have indicated on the map, but may perhaps be quite separated from it by tertiary deposits.

The crystalline formations of the Himalaya form one of the most difficult chapters in Indian geology, not only because of the inaccessibility of the districts in which they appear, but also because of the vast extent to which metamorphism there prevails, which leads one to suspect that completely crystalline schists are frequently but sedimentary formations of palæozoic age at the outside. However, thus much is certain, that the Himalaya contains not one, but two zones of crystalline rocks, the northern of which only forms the boundary division between the true mountain region and the Steppe region of Central Asia. To show this more clearly, I will describe a few sections more fully.

In the extreme west it is not possible to demonstrate the two zones, as that region is as yet too little known, and the political condition is such that a considerable time will doubtless elapse before researches can be undertaken there. If the section of Mt. Sirban, which I and Wynne have described,¹ be followed north-westward, crystalline talc schists and finally also gneissoid rocks will be seen to emerge from below the clayslates, but the boundary at the Black Mountain, beyond which no European may penetrate, will be reached before a change in the petrological characters of the rocks indicates the approach to a fresh zone of sedimentary formations. Or it may be that the first sedimentary, as well as the first crystalline, zone is wanting here in the extreme west, and thus both terminate at the Jhilum, and that further to the west the second zones approach to the

¹ Waagen and Wynne : Mem. Geol. Surv. of India, Vol. IX.

edge of the mountains? It is only more to the east, in the Kashmir territory, that it becomes possible to penetrate further north and obtain more complete sections.

If the road over the Pir Panjal pass be followed into Kashmir, one meets in rising from the plains, first the Siwalik beds, then the various divisions of the nummulitic formations, which further to the south-east towards Jummoo and also to the north-west towards the Jhilum surround isolated masses of palæozoic limestones. Lastly appear the crystalline schists, accompanied by a narrow strip of limestone squeezed in between the schists and tertiary sandstones, and in the determination of the age of which one wavers, in the total absence of fossils, between the triassic and the silurian systems. The Pir Panjal itself consists entirely of crystalline schists, but to the eastward a largish mass of gneiss appears, which, according to Lydekker, even in its petrological characters, recalls Stoliczka's central gneiss, as veins of albite granite are found included in it.¹ A part of the schists will doubtless have to be reckoned as belonging to the older palæozoic formations. I am acquainted with no particulars about the northern slope of the Pir Panjal, but it is probable that it also consists of metamorphic schists.

On the north side of the Kashmir valley, which is filled with alluvial formations, the succession of rocks recommences with carboniferous limestone and older palæozoic schists,² under which, further to the north, chloritic schists appear, which were regarded by Stoliczka as silurian. Still further north, overlying the palæozoic beds, follow triassic limestones, which, interrupted here and there by carboniferous limestones, extend to Pan Dras in the valley of the Dras river, where they are replaced by silurian beds, which finally rest, to the northward of Dras, on hornblende rocks and true syenite, which here composes the second crystalline zone.³

Another section follows a line from the Indian plain across Simla to Spiti and Rupshu. The first zone of rocks which borders the plain again consists of Siwalik beds, followed by a great extent of nummulitic beds. Under these lies an extraordinarily varied "complex" of limestones, sandstones, schists and clay-slates, which appear to be in the most varied stages of metamorphism, and which I shall have to discuss more closely further on. The ridges around Simla are composed of these schists.⁴ They rest upon true crystalline schists, numerous varieties of which border the banks of the Sutlej up to the Wangtu bridge. From this latter point commences Stoliczka's "central gneiss," which constitutes the main mass of his Pir Panjal ranges. To the north of this mountain range comes in the whole series of sedimentary formations in regular succession up to the cretaceous rocks. They occupy the whole area of Spiti, and have the highest summits in the Baralatzé range. Older rocks reappear gradually in Rupshu, and

¹ Lydekker: *Records Geol. Surv. of India*, Vol. IX.

² Godwin-Austen: *Quart. Journ., Geol. Socy. London*, XXII, p. 29; Stoliczka: *Mem. Geol. Surv. of India*, V, p. 350.

³ Stoliczka: *Mem. Geol. Surv. of India*, V, p. 348.

⁴ Medlicott: *Mem. Geol. Surv. of India*, Vol. III.

crystalline schists and granitoid gneisses reveal finally the second crystalline zone to the southward of Khorzog.¹

The dip of the strata in the first crystalline zone, in the regions now mentioned, is generally north and north-eastward; along the southern border of the second zone it is southerly and south-westerly. The fossiliferous sedimentary formations are enclosed between the two as in a basin. The strike of these zones appears in the local sections to correspond with that of the principal ranges, so that the first zone appears to follow the Pir Panjal, and the second Cunningham's Trans-Himalayan range, but on closer inspection the matter presents itself otherwise on the maps. The Baralatzte range, whose highest summits on the frontier of Spiti and Rupshu were formed of sedimentary deposits (Tagling pass), reaches, in the extension of its strike north-westward, the south edge of the second crystalline zone in the region southward of Dras, and in consequence cuts the strike of the formations, though certainly at a somewhat acute angle. The direction of strike of the sedimentary formations has therefore become somewhat more east to west, and reminds one of the direction of the strike of the Kuenlun.

The same condition obtains in Kumann as in Spiti; the richly fossiliferous beds, which have become known through Strachey's "*Palæontology of Niti*," lie north of a crystalline zone, while to the south of it massive limestones occupy the region of Naini Tal. The second crystalline zone would then have to be sought to the north of the Sutlej valley,² but it here appears obscured and covered up by extensive tertiary deposits. Schlagintweit, however, mentions crystalline rocks on the Chako La that divides the Sutlej and Indus drainage areas.³

A similar arrangement in two crystalline zones, which are divided from each other by limestones, is also observable in Nepal, on the road to Katmandu,⁴ but it would appear that it is the second zone which here corresponds to the first zone of the north-west. The latter certainly acquires an extraordinary width in this way; and it thus becomes probable that the first crystalline zone increases in its eastward course so greatly in its north to south extension, that it occupies the whole width of the Himalaya proper which the observations in Sikkim would seem to confirm.

It is first in Sikkim that the composition of the mountains offers a totally different picture. When I visited this region on a very cursory tour, I

¹ Stoliczka : *Mem. Geol. Surv. of India*, V. Geological sections across the Himalayan mountains—

The first crystalline zone appears to be thrust furthest northward at the Rotang pass, which crosses the Pir Panjal chain to the westward of the above-mentioned line, so that Stoliczka's central gneiss appears first on the northern slope of the chain in the Chandra valley, and the Baralatzte range is entirely composed of metamorphic rocks which Stoliczka considered to be in part silurian. Further westward the first crystalline zone appears soon to trend down again to the southward.

² Strachey : *Quart. Journ., Geol. Soc. London*, VII ; Medlicott : *Mem. Geol. Surv. of India*, III, Art. 3, p. 69. Strachey : *Palæontology of Niti*.

³ Schlagintweit : *Reisen in Indien und Hochasien*, III, p. 76.

⁴ Medlicott : *Records Geol. Surv. of India*, VIII, p. 93.

thought it necessary to regard the greater part of the crystalline rocks there occurring as metamorphosed younger deposits, but it appears to me that after Mallet's¹ detailed survey, this view can no longer be entertained, although this observer appears to consider the whole crystalline series in Sikkim as younger than the trias. Coming from the plains one meets here also first of all the Siwalik beds, which follow the edge of the mountains with but little interruption through the whole of Sikkim and Assam. After traversing a more or less narrow valley one comes upon not very thick sandstone with coal, and here and there plant remains,² and which should be regarded as a triassic sandstone. Over these sandstones come azoic clayslates and crystalline schists of immense thickness, which are in their turn overlaid by gneissoid rocks. On the north side of British Sikkim the succession of beds descends regularly from the gneiss to the crystalline schists, but no more sandstone appears. From this it is probable that the crystalline rocks were thrust over by lateral pressure, and that the sandstone originally deposited against them only underlies them in appearance; similar occurrences may be observed on a large scale in the Alps. It thus occurs that the coal-bearing sandstone is overlaid regularly by Mallet's Daling series in part, and in part by his Buxa series. I can now leave the crystalline formations of the Himalaya and turn again to more southerly regions.

If the valley of the Brahmaputra be crossed, one meets again in the Khasi and Garrow hills, by which the valley is bounded on the south, with extensive crystalline areas,³ whose southern side only is covered by sedimentary deposits. More extensive surfaces are occupied by crystalline rocks in the mountains east of the Irawadi,⁴ and the whole of the peninsula of "Farther India" up to its extremity is composed of similar rocks. The Andaman Islands appear also to be built up entirely of crystalline formations.⁵ Ceylon similarly is composed exclusively of crystalline rocks.

It is not necessary for me to state here the more specific age of all the crystalline rocks discussed above; indeed, remarkably few preliminary studies bearing on that question have as yet been made, although Mallet has recently distinguished a couple of formations within the older schistose series in the neighbourhood of Delhi. In one particular case, however, this more accurate determination of age is of less interest, as these formations are all devoid of organic remains. It is only with the silurian rocks that an important series of formations begins which demands closer consideration.

If we consider the development of the palæozoic formations in India in general, it will be seen clearly that they already show a development according to two different types, which I indicated in the introduction as the characteristic of the

¹ Mallet: *Mem. Geol. Surv. of India*, XI.

² Mentioned already by Hooker, *Himalayan Journals*, Vol. II, p. 24.

³ Oldham; *Mem. Geol. Surv. of India*, I; Medlicott: *ibid*, VII.

⁴ Theobald: *Mem. Geol. Surv. of India*, X.

⁵ S. Kurz: Report on the vegetation of the Andaman Islands quoted from memory, as my copy of the book in question has been mislaid. [The quotation is a mistake: only tertiary and eruptive rocks occur in the Andamans.—H. B. M.].

Indian sedimentary deposits. Genuine marine deposits with numerous marine fossils were described from the North-Western Himalaya and afterwards from the Salt Range and the Khyber pass. Thereby the extent and the distribution of the marine facies are also indicated. The other facies is found in the Indian peninsula proper, where it occupies important areas.

The most typical region for the genuine marine development of the palæozoic formations is certainly Spiti, and it may perhaps not be superfluous to describe more fully, though briefly, the petrological characters and the succession of the beds of that ground. On crossing the bridge over the Sutlej at Wangtu, one enters the region of the gneiss composing the Pir Panjal range. To the northward, and therefore to the north of the first crystalline zone, the gneiss is succeeded by overlying blue clayslates and sandstones, 3,000 feet in thickness, and which have hitherto yielded no fossils. Higher up appear lighter colored quartzites and quartzitic sandstones with subordinate beds of cellular dolomitic limestone. Bad impressions of an *Orthis* were found at one place in the sandstones. Over these again lie greenish and bluish highly micaceous sandstones with intermediate calcareous and slaty beds with obscure remains of *Brachiopoda*. These beds close the Babel series, the lowest member of the succession of beds in Spiti.

As the next member in upward succession Stoliczka recognizes the Muth series. This has a total thickness of about 1,000 feet, and begins with dark red sandstones and conglomerates, over which are light colored sandy limestones containing numerous very badly preserved fossils. The uppermost division of the series consists of white quartzites which have hitherto yielded no fossils.

The last member of the palæozoic formations in Spiti, the Kuling series, is composed of brown crumbling slates interstratified among white quartzites. The entire thickness amounts to about 400 feet. The quartzites are very rich in well preserved fossils. Stoliczka has correlated the Bhabeh and Muth series with the silurians, and the Kuling series with the carboniferous limestone.¹

These beds, although interrupted by great gaps, may be followed eastward² as well as westward³ to the north of the first crystalline zone with characters to a certain extent similar, though variously changed by metamorphism.

Perfectly different from the development first described is that of the palæozoic beds south of the first crystalline zone. We have a detailed work by Medlicott on these regions, which is extended by a later one by Lydekker. It might appear strange that I should designate these deposits simply as palæozoic. I must therefore state my reasons for this more fully. The succession of the formations which adjoin the first crystalline zone to the southward is very difficult to determine, as, on the one hand, fossils are entirely wanting, and, on the other, the beds appear greatly altered by metamorphism. As far as it has as yet been possible to explain the succession of beds, it appears to be as follows. The youngest deposits which cannot be reckoned as belonging to the nummulitics, are light coloured

¹ Stoliczka : Mem. Geol. Surv. of India, V, pp. 16-29.

² Strachey : Quart. Journ., Geol. Soc. London, VII.

³ Stoliczka : Mem. Geol. Surv. of India, V, pp. 341, 344, 348.

thin-bedded limestones with intermediate earthy beds, the whole thickness measuring from 500 to 800 feet. The material of the intermediate beds spreads itself so greatly in some sections, that the whole series appears to consist only of soft clayslate. Under these lie yellowish-red sandstones of very variable thickness, from 15 to 100 feet. These beds are best exposed on the Krol mountain, whence they are called by Medlicott the Krol group. Under these lie from 1,000 to 2,000 feet in thickness of blackish coaly clayslates, composing the Infra-Krol group. Still further down we find white quartzites, compact limestones, and thick conglomerates with sandstones, which form Medlicott's Blini (Blaini) group. These are finally underlaid by roofing slates and sandstones, which Medlicott united in his Infra-Blini group. These rest on true crystalline schists. We have thus a series of beds several thousand feet in thickness in which not a single bed or division can be determined as to its age.¹ Stoliczka, it is true, has attempted to establish a correlation with the beds on the north side of the first crystalline zone, but in so doing he leans only on suppositions, and finds it impossible to adduce a positive proof.² He holds that the crystalline schists below the Infra-Blini group represent the lower part of the Babeh series, and the Infra-Blini group with the Simla slates, the upper part of that series. The Blini conglomerate he ranks with the lowest divisions of the Muth series, the Blini limestones with the middle

¹ In order to characterize with the fewest possible words this absolute uncertainty, I had, when alluding to these beds in a short address to the German Geological Society (*Zeitschrift d. D. Geol. Ges.* XXVIII, p. 644), used the expression that these beds might possibly also be nummulitic; this was certainly rather a strong expression, but it expressed the position of things. I believed at that time that the strata around Simla might also, on account of the almost absolute absence of all organic remains, be reckoned to the peninsular type, but recent discoveries by Lydekker have clearly shown the contrary. But even this error does not justify the manner in which Medlicott has on that account attacked me (*Records Geol. Survey of India*, X, p. 100) without bringing home anything positive against me. Mr. Medlicott appears, above all things, to have overlooked the fact that the statements in question were not presented as a paper, but as an oral address, which I was compelled to make as brief as possibly could be. All my audience knew very well that I had only given a sketch, and that all details and proofs were partly already printed and partly reserved for a special essay. It is not possible to use "foot notes" in speaking. What, therefore, Medlicott wrote about the purloining of the Key to Indian Geology, I may ignore with a clear conscience; it merely proves that Medlicott's criticism was written in a very high state of excitement. But I must express my deepest regret that the few words which I spoke at Jena, and which I thought quite harmless, should not only have given occasion for contemptuous utterances about the whole science of palæontology, but also have served as a pretext to reproach the highly honourable German Geological Society with a system of mutual laudation, and even the whole Teutonic race with being sunk in barbaric instincts. Finally, I cannot avoid remarking that I should certainly have expected from the Director of the Indian Geological Survey very much more considerate treatment after having sacrificed to the service of the department my health, fortune, and means of living in Europe.

[Mr. Medlicott confesses with sorrow that he did become rather excited at Dr. Waagen's short address to the German Geological Society. For the rest, those who choose cannot fail to discern that impatience at premature and oracular speculation indicates respect, rather than contempt, for the science of palæontology.—H. B. M.]

² Stoliczka: *Mem. Geol. Surv. of India*, V, p. 141.

divisions, and the white quartzites following the limestones with the uppermost divisions, while he claims the quartzites of Boileau-ganj hill and the garnetiferous mica schists of Jako as equivalent of the Kuling series, or the carboniferous limestone. In the Infra-Krol sandstones he finds so great a petrological resemblance to the Bunter sandstone of the Alps, that he is inclined to regard it as lower triassic, when the Krol limestone would fall to the upper Trias. But now it is to be observed that Medlicott, after close study of the garnetiferous mica schists of Jako, regards them as a metamorphosed facies of the Infra-Krol beds, and that elsewhere the Krol limestones appear to pass into Medlicott's great limestone, which has been recently identified by Lydekker¹ with considerable certainty as carboniferous limestone. For the present, therefore, more reasons favour the assumption of the palæozoic age of the whole rock series of the neighbourhood of Simla, than the transfer of a part of the beds to the Trias merely on account of petrological resemblances.² If we proceed eastward from the neighbourhood of Simla, it appears to be Medlicott's great limestone especially that constitutes the limestone formations of the outer zone. The most easterly point, before reaching the boundary of Nepal, is the neighbourhood of Naini Tal and Almora, in which Medlicott refers to thick limestone, which he identifies with his Krol limestone, and below which reddish, greenish and grey slates appear to represent the Infra-Krol group. To the north these rocks are cut off by eruptive formations, which are succeeded still further north, near Almora, by crystalline rocks.³

Of the region around Katmandu, Medlicott⁴ only has furnished any particulars. There, after traversing the tertiaries, one crosses a narrow zone of compact and partially crystalline limestone with subordinate slate beds, then an equally narrow band of crystalline rock, when an extensive limestone region is immediately entered upon, which stretches away to several miles beyond Katmandu and there gives place to a second crystalline zone. Of the age of these limestones nothing is known, as fossils are entirely wanting. Medlicott regards them as corresponding to his Krol group, and it is quite probable that they are for the most part of palæozoic age. What lies beyond the second crystalline zone is absolutely unknown.

¹ Lydekker : Records Geol. Surv. of India, IX, p. 157.

² It is true that Gümbel describes (Sitzungsber. bair. Acad. d. Wiss., 1865, II, p. 354) a specimen of rock said to come from the Schlagintweit's collections and to have been found at Dharampur, near Solen, in the province of Simla, which specimen contained *Lima lineata*, Schl., *Nat. gaillardoti*, Lep., and *Nat. simlaensis*, Gümb., and would thus indicate the existence of the trias. But when one considers that all other observers have found the rocks around Simla devoid of fossils, and further that Schlagintweit adduces cretaceous fossils from the exclusively palæozoic region of Kudappa (Reisen in Indien und Hochasien, I, p. 144), less weight will be accorded to this specimen, and the possibility of a mistake in labelling will not be considered as absolutely inadmissible.

³ Medlicott : Mem. Geol. Surv. of India, III, p. 69. See also Strachey : Quart. Journ. Geol. Soc., London, VII.

⁴ Medlicott : Records Geol. Surv. of India, VIII, p. 93.

Lydekker's work in the region west of Simla is of the highest interest. In a section across the Pir Panjal from Suru to Shahabad in Kashmir,¹ he distinguished as cambrian certain crystalline schists overlying the gneiss, and above them as silurian, a series consisting of dark-red and white quartzites, dark soft schists or slates with carbonaceous stains and ferruginous concretions, 50 to 200 feet thick, and dark clayey, often bituminous limestones which pass up into thick black clayslates. These beds are cut off (on the south) by a fault, and are succeeded immediately by tertiary rocks, out of which, however, a thick limestone reef (the great limestone) protrudes, which shows itself by the presence of *Fenestella* as belonging probably to the mountain limestones. Still further westward, on the Jhilm, apparently only the limestones of the silurian series remain, which are there regarded by Wynne as triassic.

About the palæozoic beds of the neighbourhood of Abbotabad, and still further west, there is little to be said; they are thick dark clayslates with intermediate sandy beds which were designated by myself and Wynne as Attock Slates, because they attain a great development on the Indus near Attock. In the direct strike of these beds lie the beds of the Khyber Pass, from which silurian fossils are quoted by Godwin-Austen.²

Of the deposits of the first facies only the palæozoic beds of the Salt Range remain, which require to be more closely discussed. The Salt Range is in many respects a most interesting district, because it is here that transition formations between the deposits of the two facies are exposed. In the western part of the Salt Range the palæozoic formations are as follows: At the top lie brownish-yellow sandy clayey calcareous beds, with intermediate harder beds, about 100 feet thick, which contain innumerable fossils, and among them the *Cephalopoda* described by me. Below these follow compact limestones with numerous *Producta*, &c., about 200 feet thick; then follow sandstones with intermediate carbonaceous beds and numerous fossils, with a maximum thickness of from 150 to 200 feet. Under these lie violet clays with hard marls and inclusions of red and green sandstones often of considerable thickness, even up to 300 feet.

They are underlaid by dark red sandstones, often as much as 300 feet in thickness. Bright red marls with gypsum and rock-salt form the base of the whole series of beds. It may be seen already from this succession of beds that the older palæozoic rocks along the whole length of the Salt Range are developed with a facies corresponding to the peninsular type, for the saliferous beds and the overlying sandstones are equally developed throughout the whole Salt Range, only in the western part are the sandstones replaced by conglomerates. Above the red sandstones, however, follow, in the eastern part of the Salt Range, first of all a series of carbonaceous sandstones with fucoids and a small brachiopod most nearly allied to *Obolus*, from which Wynne has concluded prematurely that the beds are silurian. Higher up we find a very thick series of sandstones, shales, dolomitic

¹ Lydekker: Records Geol. Surv. of India, IX, p. 161.

² Godwin-Austen: Quart. Journ. Geol. Soc. London, XXII, p. 29; Waagen and Wynne: Mem. Geol. Surv. of India, IX, p. 334.

sandstones, and shales which must, on the whole, correspond with the upper palæozoic beds in the western part of the range. It is very difficult to follow up the several beds through the several phases of their transition from west to east, but I endeavoured to do this at least for the lowest beds of the so-called carboniferous limestone, and found that they pass, in progressing from west to east, first into coarse-grained white sandstones (which contain a very few fossils, chiefly rolled fragments of corals), then into a very coarse conglomerate, with boulders as large and larger than a man's head, and finally into a homogeneous gray-green sandstone without any fossils, which appears to stand in close relation to Wynne's magnesian sandstone.

We have now entered into the domain of the second facies of the palæozoic beds of India, and may turn at once to the typical development of the same in the Vindhyan mountains. Several papers have already been written on the Vindhyan mountains, and their structure and composition are pretty accurately known. According to Mallet¹ there rests upon the gneiss a thick formation of crystalline and argillaceous schists with quartzites and limestones,² and on these the Vindhyan formation lies quite unconformably. The latter formation begins with sandstones, which are soon overlaid by thin-bedded silicious limestones, mostly light brown and grey in color, with intermediate earthy beds of variable, but considerable thickness. The total thickness of this lower half of the formation ranges from 1,000 to 1,500 feet; above it comes with apparently but slight unconformity a red sandstone formation of very great thickness which includes intercalated beds of shales and conglomerate of greater or lesser thickness, and in the upper beds only, a rather considerable bed of compact blue limestone. Over the limestone sandstones occur again, and attain locally a thickness of 3,000 feet. This closes the Vindhyan formation. In the whole of this series of many thousand feet in thickness not one single fossil has been discovered, although special attention was directed to that point by the Geological Survey. The only point of support one has on which to fix the age of these formations is that rolled debris of Vindhyan rocks is found already in the Talchir conglomerate, which is certainly either very young palæozoic, or very old mesozoic, age, shewing that the Vindhyan series should probably be reckoned among the old palæozoic formations.

Another palæozoic area of similar type has been described by King³ from the Madras region. As in the Vindhyan mountains an upper and lower division of the formation has been recognized, so also has King divided the palæozoic deposits of the Madras region into two different groups, of which he calls the lower, the Kadapa, the upper, the Karnul series. Both of these are more highly metamorphosed than are the rocks of the Vindhyan mountains. The lower of the two series rests on the gneiss, and consists chiefly of clayslates and quartzites,

¹ Mallet : Mem. Geol. Surv. of India, VII.

² These beds have recently been distinguished as the Gwalior and Arvali series, but are in my map still mostly shown as crystalline, as the materials for cartographic distinction were not sufficiently advanced.

³ King : Mem. Geol. Surv. of India, VIII.

while the upper series, which rests unconformably on the lower, includes numerous limestones besides quartzites and clayslates. The same series of beds was observed by Foote¹ along the whole southern edge of the great basaltic region in the South Mahratta country. Here, as in the Madras region and the Vindhyan mountains, not a trace of a fossil is to be found.

Greatly richer in inclusions of the remains of organic beings, and consequently far more interesting to the palæontologist, are the Indian mesozoic formations. Here also two types are distinguishable, in accordance with which the deposits in different parts of the country are developed; but here they are also characterized by their fossils. If we first look more closely at that kind of development which from its principle occurrence in the Himalayas has been termed the "Himalayan type," and which contains exclusively marine sediments, we shall find it best developed in the North-Western Himalayas, northward of the first crystalline zone. Above the carboniferous limestone comes a long series of limestones alternating with softer beds, in which the faunas can be very well divided according to the several horizons. Stoliczka² has left us the most reliable information about these formations, the occurrence of which, in Spiti especially, he has more fully described.

The trias there begins with a bed of limestone, consisting almost entirely of the shells of *Halobia lommeli* (as determined by Stoliczka), overlying crumbling shales with *Spirif. keilhavi* and *Prod. semireticulatus*.³

Above this limestone follows a kind of "giant-oolite," which yielded the greatest number of the fossils described by Stoliczka. It passes up into thin-bedded earthy limestones without fossils. This series of beds composes Stoliczka's Lilang series. Beyrich⁴ has tried to make it appear probable that the whole fauna derived from these beds belongs to the Muschelkalk period, but that possibly the upper beds, which in Spiti are poor in fossils, might be fossiliferous in the north of Kumaun and in other places, and contain faunas of the Keuper age.

The next higher division recognized by Stoliczka is the Para limestone. This is but a few feet thick in Southern Spiti, but increases in thickness to about 1,000 feet to the northward of the Baralatze pass. They are dolomitic limestones, partly massive, partly thin-bedded, and then very earthy. The only fossils they have yielded are *Dicerocardium himalayense*, Stoliczka, *Megalodon triqueter* Wulf., some *Chemnitzias* and *Neoschizodus*. Above these beds follows a series of limestones, about 200 feet thick, whose lowest beds, however, appear to belong already to the lowest jura (lias). Stoliczka calls these limestones Tagling limestones.

¹ Foote : Mem. Geol. Surv. of India, XII.

² Stoliczka : Mem. Geol. Surv. of India, V.

³ Among the materials which Stoliczka collected on his tour to Yarkand, I saw a *Ceratite* of the type of the Salt Range forms, together with a globose *Ammonite* from the same bed; the 'Bunter Sandstein' appears thus to be represented also in other places. Also *Amn. peregrinus*, Beyr. and the Spiti rock specimens described by Gümbel, point to the existence of the Bunter Sandstein.

⁴ Beyrich : Abhandl. Akad. d. Wissensch., Berlin, 1866, p. 141-147.

They are brown or grey, sandy or earthy, often oolitic, more rarely compact and thick-bedded, and contain innumerable fossils, which can in great part be identified with species from the Kössener beds. The occurrence of *Nerinaeas* and large *Belemnites* in these beds is remarkable. In two places, on the Parang pass and the Tagling pass, Stoliczka noticed in the uppermost beds of these limestones, which appeared to be of blue grey colour and compact, some species common to the Hierlatz beds, according to which the limestones would have been considered as liassic. This is the only case in which in the whole vast region of India liassic fossils are mentioned with confidence. The Tagling limestone is covered by hardened shales with *Posidonomyas*; they form the transition to the well-known Spiti shales which long since furnished *Ammonites* to the European collections. It has not yet been attempted to carry out a closer sub-division of these beds; but it is at any rate quite certain that the greatest number of the fossils were derived from a bed which corresponds in age with the uppermost jura of Europe (the Kimmeridge and Tithonian groups), and that Stoliczka's views as to their age, and also many of his determinations of species, must be considered as erroneous. The thickness of the Spiti shales hardly ever exceeds 500 feet, but is generally less. Above them follow sandstones (Gieumal sandstones) which contain in Spiti but a very meagre fauna, and in which farther to the westward I observed *Trigonias* resembling those of the *Oomia* group in Kachh. These sandstones conclude the jurassic formation. The cretaceous series is represented in Spiti by the Chikkim limestones and Chikkim shales, the former of which enclose fragments of the shells of *Rudistæ*.

The distribution of the secondary rocks northward of the first crystalline zone eastward from Ngari-Khorsum is but very little known. Strachey mentions jurassic *Ammonites* from Eastern Nepal; but this statement has not been confirmed recently. Jurassic *Ammonites* have, however, been cited with greater certainty from the immediate neighbourhood of Lhasa.

Not nearly so complete a series is that of Mount Sirban, but it is not the less interesting, because one of the most easterly localities for marine fossils, south of the first crystalline zone. Here lie, unconformably on the palæozoic schists, red sandstones and thick silicious dolomites, whose position in the mesozoic succession of beds remains uncertain, as fossils are wanting. Above these come dark, thick-bedded limestones, with silicious concretions, and sections of *Megalodon* and *Dicercardium*. The limestones pass up into thin-bedded limestones and slates, which appear to be equivalent to Stoliczka's Tagling limestone. The Spiti shales rest unconformably on these, and are succeeded upwards by grey sandstones, the equivalents of the Gieumal sandstone, and finally by hard, sandy limestones, with Gault fossils. Grey, thin-bedded limestones without fossils conclude the mesozoic series. With similar development, but generally decreased thickness, and with the Spiti shales generally replaced by a few limestone beds, the mesozoic formations stretch away westward along the Chittapahar into the country of the Afridis.

The mesozoic formations of the Salt Range are rather better developed. Above the uppermost beds of the palæozoic come, firstly very hard, flaggy limestones,

then greenish marls, then sandstones, and finally, again limestones. The *Ceratites* described by De Koninck occur throughout all this series, which in age very probably represents the Bunter Sandstein of Europe, although *Myophorias* resembling a *Muschelkalk* species occur already in the uppermost limestones. Above these lie variegated beds, partly sandstone, partly marls, with many fragments of coal and extremely few ill-preserved mollusks. Not till the middle jurassic period do beds appear again, which are determinable according to their age. These are limestones with but few fossils, over which follow again variegated beds with intercalated alum shales. Then follow oolites, and finally, distinct Kelloway beds. These are overlaid by black shales resembling the Spiti shales, and with which the jurassic series concludes. Above them lie green sands with neocomian fossils. These are succeeded by beds of very varied constitution, now resembling the ores of the Kressenberg, then sandstones, then again yellow marls, rich in fossils, which perhaps represent the uppermost chalk, but whose exact age can only be determined with certainty after careful working out of the fossils. This is the succession of beds in the western part of the Salt Range; in the eastern part follow, above Wynne's magnesian sandstone, red slaty sandstones, with numerous salt pseudomorphs, probably triassic in age, and above them greyish green sandstones which may well belong to the cretaceous period.

Southward of the Salt Range a complete series of the secondary formations is nowhere to be found, but only individual members of the same which appear sporadically. The marine deposits of the age of the trias especially have disappeared almost entirely; only from Burma has Mr. Theobald brought some specimens of *Halobia* cf. *lonmeli*, which lead me to conclude the existence of marine triassic beds. Their geographical distribution can only be made out with difficulty on Theobald's¹ map.

The marine beds of the jurassic system have a wider extension. In my work on the Kachh *Cephalopoda* I already drew attention to the existence in various places under the sands of the Rajputana desert of jurassic beds which have in some cases already yielded fossils. Nothing is known of the succession of beds, or their occurrence elsewhere. The rocks are sandstone and shales; the fossils chiefly indicate a relationship to the Katrol sandstone. To indicate the distribution of the jurassics in this region, I have in my little map placed some jurassic patches at random within the limits of the Rajputana desert.

These jurassic beds connect those of the Salt Range with the Kachh beds. Unfortunately the lowest beds of the Kachh jura are not exposed, as the crystalline rocks only crop up to the northward of the Runn, while the lowest beds of the jura first appear from under the Runn, some 10 to 15 miles to the southward. These lowest beds form the Patchum group.² They are earthy sandstones of yellowish or yellowish grey colour, containing numerous gasteropods and bivalves.

¹ Theobald : Mem. Geol. Survey of India, X.

² Waagen : Jurassic Fauna of Kachh ; Introduction.—Palæontologia Indica.

They are succeeded by grey marly limestones, with numerous *Brachiopoda* and corals, which close the Patchum group. Above them lie limestones and oolites, with intermediate clayey beds (*Macrocephalus* beds), then clays with nodules of ironstone (*Anceps* beds), then white marly limestones with *Peltoc. athleta*, and finally, oolites with *Aspidoc. perarmatum*, &c., of which the Charee group is composed. The next higher group, the Katrol group, includes but two divisions: the Kuntkote sandstones, soft iron-stained sandstones, with fossils of the type of the higher Oxford beds; and the Katrol sandstones, harder, partly calcareous sandstones, of grey and red colour, with a true Kimmeridge fauna.¹ The last group that was distinguished is the Oomia group, which forms two sub-divisions: one of sandstones and conglomerates with marine fossils, amongst which a couple of "Portland" species occur; the other of sandstones and shales with plant remains. Covering the jurassics, Stoliczka discovered, finally, a bed of oolite, which yielded two species of Aptian fossils.

I have already pointed out, in my work above quoted, the remarkable fact that the type of the marine fossils occurring in Kachh reminds one much more of the far distant European jurassic formations than of the closely adjoining jurassic beds of the Himalayas. While numerous European species of *Cephalopoda* occur in Kachh, only a single Himalayan species has been identified with a European one; whereas the numerous species of the genus *Cosmoceras*, as well as the great number of *Aucellas*, indicate a certain relationship between the Himalayan and Russian juras. It appears, therefore, that two great jurassic regions, the Europo-Indian and the Russo-Himalayan, meet in the Punjab, and that they were perhaps connected with each other by a narrow strait, as the jura of the Himalayas and the jura of Kachh have only five species in common. We know, however, so little about the geological conditions of the Hindu Kush, that it is quite impossible to draw any conclusion as to the extension of the jurassic sea in a north-westerly direction.

This brings the marine deposits on the western side of India to an end, with the exception of certain cretaceous beds, which I shall consider more closely further on. Marine beds appear next again on the south-east coast of the Peninsula, and they are jurassic. The sandstones and shales which underlie the South Indian cretaceous rocks, and which were described by H. F. Blanford as the Ootatoor plant beds, have long been known. Oldham² already expressed a most decided opinion, that these plant-bearing beds belonged to a system of beds differing from the cretaceous system; and Stoliczka³ believed himself justified in determining the equivalent *Sripermatour* beds by their fossils to be of jurassic age. It is only recently that these deposits have been fully described by Foote.⁴ At

¹ On the character of this fauna, see also Beyrich; *Sitzungsber Akad. d. Wiss., Berlin*, Sitzung vom. 8 März. 1877, p. 97.

² Oldham: Note in Blanford's Memoir; *Mem. Geol. Surv. of India*, IV.

³ Stoliczka: *Records Geol. Surv. of India*, I, p. 59.

⁴ Foote: *Mem. Geol. Surv. of India*, X, p. 63.

that place are coarse white sandstones, which probably lie directly on the gneiss : above these follow sandy shales, which in their turn are covered by about 10 feet of soft friable sandstone, above which occur finally the fossiliferous beds, indurated, and often porcellanoid shales of light bluish-grey colour, and from 8 to 10 feet thick. The fossils consist of numerous plant remains, mixed up with marine shells, which latter, however, are unfortunately so badly preserved, that their specific determination is impossible. To me¹ the Ammonites appeared somewhat like neocomian forms, but much importance must not be attached to the type in the absence of specific agreement. More recently similar beds have been found by King² in the lower Godavari valley, and their fossil contents have been determined by Stoliczka as corresponding to the fauna of the Kachh-Oomia beds. Since then it has been shewn that these semi-marine deposits have a considerable development in the Godavari district, and form two groups, which King distinguishes as the Tripetty sandstones and Ragavapuram shales.³ The upper group consists of dark-brown ferruginous sandstones and conglomerates, which become softer and more friable as you descend, and which include lenticular masses of shales, with plant remains and marine shells. The lower group, which corresponds closely, according to King's view, with the Sripematur beds, consists only of hardened shales, which include the remains of marine shells, as well as plant remains. None of these molluscan faunas have as yet been closely examined, and it is only known that many species agree with others from the Kachh-Oomia beds. This concludes the series of localities belonging to the jurassic period, and containing traces of marine fossils, and we may now turn to the cretaceous formations; but for this purpose we must return again to the west.

We have seen that certain beds in the Salt Range which appear from below the nummulitic rocks, and have a tolerably wide extension, may possibly represent the cretaceous rocks. Similar deposits, developed on a large scale, were observed by Ball⁴ in the country of the Luni Pathans; but he discovered no decisive animal forms in them. The same beds are also cited by Blanford⁵ as underlying the nummulitic beds in Sind; but these are well exposed at but few places. The existence of equivalent deposits in Kachh is doubtful. It is true Wynne⁶ distinguished a sub-nummulitic group there; but it is very doubtful whether its members are equivalent to the Sind and Salt Range beds.

Of very high interest are the so-called Bagh beds, which reach far into the interior of the Peninsula in their very abnormal extension. They appear

¹ Waagen : *Palæontologia Indica* ; Jurassic Fauna of Kutch, I, p. 236.

² King : *Records Geol. Surv. of India*, VII, p. 159.

³ King : *Records Geol. Surv. of India*, X, p. 56.

⁴ Ball : *Records Geol. Surv. of India*, VII, p. 153.

⁵ Blanford : *Records Geol. Surv. of India*, IX, p. 11.

⁶ Wynne : *Mem. Geol. Surv. of India*, IX, p. 66.

to occupy invariably a bathrological position below the basaltic flows; while certain grounds exist for regarding the above-quoted deposits in the Salt Range and Sind as in part contemporary with the basaltic eruptions. In any case, according to their marine fossils, the Bagh beds represent a part of newer (middle) chalk. Their distribution is confined to the lower Nerbudda valley, where they appear in many places below the trap. Blanford gives full information about these beds in his excellent description of Western India.¹ At Cherakhan, the richest locality for fossils, the beds shew the following section: At the base, sandstone and conglomerate, 20 feet thick; above these, concretionary limestone with silicious excretions, 20 feet thick; still higher up, clayey limestone, with many fossils, particularly echinoderms, 10 feet thick; and finally, hard limestone, locally cellular, with numerous *Bryozoa* and fragments of oysters, 10 to 20 feet in thickness. The echinoderms were closely examined by Duncan,² who ascertained that the greater number of species were identifiable with Upper Greensand species. It is doubtful whether the sandstones and conglomerates which form the base of the above section should not be regarded as a western extension of the Jabalpur or Mahadeva beds, which forms a connection between these and the Kachil plant beds. Southward of the Tapti river there are hardly any more localities shewing Bagh beds, so that the southern boundary of these beds may be assumed to be here. Still farther south, we meet with no further marine mesozoic deposits on the western side of the Peninsula. On the east side, on the contrary, we find the cretaceous rocks of the neighbourhood of Trichinopoly, which are so exceedingly rich in organic remains.

The cretaceous deposits of Trichinopoly district have, it is true, been worked out palæontologically by Stoliczka in a very remarkable way; but it still appears that there are many points of interest to be determined with reference to the stratigraphy of these formations. Our present knowledge of the relations there existing is based mainly on H. F. Blanford's compendious Monograph.³ He recognizes three principal groups, which are deposited on the primary rocks in overlapping beds. The lowest, or Ootatoor, group begins with coral limestones, which are overlaid by fine sandy clays and sandstones with subordinate limestone. Above these follows the second, or Trichinopoly, group, consisting of sandy clays and conglomerates, which include, but only in the northern part of the area, numerous limestones abounding in fossils. The uppermost of the three groups is termed the Arialoor group; but at its base a sub-group, the Valudayur group, has been distinguished. The latter consists of limestones and conglomerates which pass up into sandy concretionary limestones with numerous fossils. The age of all these beds was determined by Stoliczka as belonging to the period from the Cenomanian to the Senonian.⁴ It was thought

¹ Blanford, W. T.: Mem. Geol. Surv. of India, VI; and Records Geol. Surv. of India, V, p. 82.

² Duncan: Quart. Journ. Geol. Soc., London, XXI, p. 349.

³ Blanford, H. F.: Mem. Geol. Surv. of India, IV.

⁴ Stoliczka: Records Geol. Surv. of India, I, p. 59, and further on in many places.

till lately that these South Indian cretaceous rocks were limited to the Trichinopoly basin, but more recently traces of them have been found further north. Foote already met with loose blocks of a cretaceous rock in the neighbourhood of Sri-permatur,¹ but was unable to trace the bed *in situ*. King², on the contrary, discovered richly fossiliferous rocks, of probably cretaceous age, in the Godavari district, below the trap which there occurs sporadically. These he regards as Lametas, but the fossil species there collected require to be more accurately determined.

The most northerly localities with marine cretaceous rocks on the east side of the Indian Peninsula are the Khasi and Garrow hills, or, as Medlicott terms it, the Shillong plateau. On descending from Cherra Punji to the south, one meets below the nummulitic beds first of all a sandstone 200 feet thick and of uncertain age, fossils being entirely unknown in it. Below it alternate limestones and sandstones, with a thickness of about 500 feet, which appear finally to terminate with conglomerates at their base.³ Stoliczka⁴ has submitted the fossils collected by Medlicott to a careful examination, and found that the highest fossiliferous beds contain Corals and Bryozoa; in the middle beds Cephalopoda predominated (*e. g.*, *Amm. planulatus*, *dispar*, *Orbignyanus*, Gein., *pacificus*, Stol. &c.), while the lower part which is best exposed on the Theria Ghât includes numerous gasteropods and pelecypods, the greater number of which agree with South Indian species, but amongst which there are also many novelties. The cretaceous beds now under consideration appear, on the whole, to correspond most nearly with the South Indian Arrialoore group.

To the southward of these beds cretaceous rocks appear again below the nummulitic deposits in Burma,⁵ but they require closer examination.

This is the last spot at which marine mesozoic formations appear in India. The remaining beds of similar age are vast accumulations of sandstone which show themselves by their inclusions of plant-remains and by the total absence of marine fossils to have been formed in inland basins. It is impossible for me to describe closely and fully the several beds composing these deposits, particularly as a good deal of uncertainty still exists among Indian geologists as to the correlation of the sub-divisions in the different areas of deposition. This uncertainty is, however, not unnatural when one considers that the various inland basins in which these beds were deposited were very probably but slightly or not at all connected, so that only the palæontological data can indicate the correspondence of the several groups. The very scattered distribution which these deposits exhibit when represented on the map may probably be due just as

¹ Foote : Mem. Geol. Surv. of India, X.

² King : Records Geol. Surv. of India, VII, p. 159.

³ Medlicott : Mem. Geol. Surv. of India, VII, p. 168.

⁴ Stoliczka : In Medlicott's Mem. *ibid.*, p. 181.

⁵ Theobald : Mem. Geol. Surv. of India, X.

much to denudation as to any peculiarity in the manner of original deposition. Oldham's¹ view that the great hydrological basins of the Indian Peninsula were already at the period of deposition of the Damuda beds similar to what we now know them to be, and that, consequently, the geographical distribution of the plant beds agrees on the whole with these river basins, is one of particular interest.

The whole of this associated series of formations, with the exception of those which correspond in age to the upper cretaceous, has recently been designated in India the Gondwana series, and the following groups in ascending order have been generally recognized: 1, the Talchir; 2, the Damuda; 3, the Panchet; 4, the Mahadeva or Rajmahal; 5, the Jabalpur; but this succession of beds is subject to considerable change according to whatever basin a locality may be situated in. H. Blanford² has distinguished with much skill certain geographically limited regions which show the succession of beds developed according to various types. The following are the regions adopted: I, Western Bengal; II, Orissa, Sirguja, South Behar, and South Rewah; III, the Satpura basin; IV, the Godavari basin; V, the deposits in the neighbourhood of Madras and Trichinopoly; VI, Kachh. The two last regions need not be noticed by us now, as they contain beside the plants also the remains of marine animals, and as the deposits occurring in them have already been treated of; but with regard to the remaining divisions, it will be judicious to adopt the divisions given by H. Blanford, but one more province must be added, No. VII, Sikkim, as there also only plant beds occur. It would hardly be of any interest to enumerate all the innumerable sandstones, shales, conglomerates, and coal seams which compose the Gondwana series, and aggregate to some 12,000 feet in thickness; it will suffice to represent simply the type of the deposits in the different regions. The first of Blanford's regions includes the carboniferous basin of the Damuda valley, the Rajmahal hills, and countless little coal basins, often not more than a square mile in extent, distributed over the gneiss plateau which extends westward from the lower course of the Ganges. The development of the beds in the Raniganj coal-field, as described by W. T. Blanford³ may pass as a type for this whole region, with the exception of the Rajmahal hills.

The succession of beds in that region is as follows. At the top lie perfectly unfossiliferous coarse sandstones and conglomerates about 500 feet thick; Blanford calls them the "Upper Panchets," but it is hard to decide whether they should not perhaps be reckoned to the Rajmahal group. Below these follow the true Panchet beds, which consist of coarse sandstone and red shales, which passes down into greenish and grey clay with fine-grained sandstones. Their thickness is about 1,500 feet. These deposits have yielded numerous fossils, and amongst them are not only plant remains, but also *Vertebrata* (fishes, *Dicynodon orientalis*,

¹ Oldham: Records Geol. Surv. of India, III, p. 5.

² H. Blanford: Quart. Journ. Geol. Soc., London, XXXI, p. 519.

³ W. T. Blanford: Mem. Geol. Surv. of India, III.

Hux., *Gonioglyptus longirostris*, Hux., *Pachygonia incurvata*, Hux., *Ankistrodon*, sp., &c.,) and *Estheria*. Lower down follows the Damuda group, which is divisible into three divisions according to Blanford; uppermost lie the Raniganj carboniferous beds, about 5,000 feet thick, consisting of coarse and fine-grained sandstones and shales, with intercalated coal seams, which may be followed over great distances; fossils are common, but consist only of plant remains. In the middle lie the ironstone shales, about 1,400 feet thick, and consisting of black carbonaceous shales with numerous beds of clay ironstone. At the base lie the lower Damuda or Barakar beds, coarse conglomerates and white sandstones with numerous coal seams, which are, however, rather irregular, and thin out frequently within short distances; they contain plant-remains, and are about 2,000 feet thick. The lowest group recognized by Blanford is the Talchir group, which is composed of coarse white or bluish-green sandstones at top, below them of fine greenish-grey clay, which is in part sandy, then of sandy shales and fine-grained sandstones; finally comes as basement the so-called 'boulder bed,' consisting of large rounded blocks of older rocks which bear traces of carriage by ice, and are embedded in a fine clayey sandy matrix. Fossil plants occur in the upper beds of the group, but are very rare; the thickness of the group is about 800 feet.

This completes the type of the deposits for the whole of Western Bengal, with exception of the Rajmahal hills. On these no detailed accounts are yet available¹; but it is generally known that Talchir and Barakar beds are well developed there. Over them lie coarse sandstones (Oldham's Doobrajpur group), which may perhaps correspond with the Panchet group, but which may also have to be reckoned to the lower series. Above these follow, with universal unconformity, the Rajmahal beds, alternations of basalt (?) with sandstones and shales which contain the well-known Rajmahal plants.

If we turn to H. Blanford's second province we see a good development of the lower beds. The Talchirs and Barakars occur in great force; the Raniganj and Panchet beds appear to be absent, but the Rajmahal and Jabalpur groups, on the contrary, appear sporadically at several places. Of the greater part of this region detailed descriptions are still wanting, but the Talchir coal-field may be taken generally as the type.² The Talchir group is there found resting on primary rocks; it begins with the highly characteristic 'boulder bed,' above which follow fine-grained sandstones and blue shales with calcareous concretions. The total thickness of the group is from 500 to 600 feet. A few plant-remains are found in the upper beds. These are succeeded upward first by coarse sandstones, then by shales, which attain together a thickness of about 100 feet. These are covered by about 150 feet of carboniferous shales, above which come finally coarse, highly felspathic sandstones, and dark micaceous shales

¹ Volume XIII of the Memoirs of the Geological Survey of India is not as yet accessible to me.

² Mem. Geol. Surv. of India, I, and W. T. Blanford: Records Geol. Surv. of India, V, p. 63.

with clay ironstone beds aggregating about 1,500 feet in thickness, and which conclude the Damuda series.

Higher up follow, unconformably, conglomerates and coarse sandstones, which were originally regarded as representatives of the Mahadeva group, and which should perhaps still be regarded as such, but this question is hard to decide in the total absence of fossils. The thickness of this latter division ranges from 1,500 to 2,000 feet. To the south-east of Talchir, however, unquestionable Rajmahal beds appear in the Atgarh coal-field; in South Rewah, on the contrary, the deposits of the Jabalpur group rest directly on the beds of the Damuda formation, and are of great extent and thickness.

Of all the provinces the Satpura basin shows the most perfect series of beds.

Medlicott¹ distinguishes numerous groups which constitute the following series. First of all is the Talchir 'boulder bed,' resting on the crystalline rocks, above it come greenish and reddish clayey sandstones and sandy clays, also belonging to the same group. On these lies the Barakar group, consisting chiefly of sandstones with intercalated coal seams, and having a thickness of from 400 to 500 feet. Higher up follows a system of shales with included sandstones, within which Medlicott distinguished three groups, Motur, Bijori, and Almod. In the second of these remains of an *Archegosaurus* were discovered. Their total thickness is from 3,000 to 4,000 feet. These are succeeded upwards by the Mahadeva series, which also forms three groups: at the base, the Pachmari group, consisting almost entirely of sandstones, and ranging in thickness up to 8,000 feet; in the middle comes the Denwa group, composed of clays and sandstones, with occasional thin limestone beds, in all 1,200 feet thick. At the top comes the Bagra group, grey and red conglomerates, 800 feet in thickness. The series is capped by the Jabalpur group, consisting of soft sandstones 500 to 600 feet thick.

Of some parts of Blanford's fourth province we have again very good descriptions, especially those of W. T. Blanford, of the neighbourhood of Nagpur.² Here, again, as in Bengal, Orissa, and on the Nerbudda, we have first the Talchir boulder bed resting on the gneiss, but there is little more to be seen of the beds of that group. Above follow chiefly hard yellow sandstones, sometimes available as millstones, which compose the Kamthi group. Of the age of this group, as compared with the horizons recognized and described in other basins, it is very difficult to say anything with certainty, but it might perhaps be not quite erroneous to place the Kamthis on the border of the Damuda and Panchet formations.³ Above them the fresh-water beds of the cretaceous series (the Lametas) are well developed.

¹ Medlicott: Mem. Geol. Surv. of India, X.

² W. T. Blanford: Mem. Geol. Surv. of India, IX, p. 295.

³ Dr. Feistmantel, in an essay apparently published in Calcutta (without mention of the place of publication, of the printer, or of the date), desires to have the Mangli beds, with *Brachiops laticeps*, Owen, regarded as Panchet, while Blanford asserts very distinctly that those beds are not separable from the remainder of the Kamthis which Feistmantel assumes to be Damudas.

The succession of beds on the Lower Godavari, which W. T. Blanford and King have described in several papers in the Records, is more complex. The following tabular statement has been recently put forward by King:—

		Godavari District.	Nizam's Dominions.	Central Provinces.
UPPER GOND- WANAS.	<div> <div>Jabalpur</div> <div> <div>Marine fossils and plants.</div> <div> <div>Tripetty sandstones.</div> <div>Ragavapuram shales.</div> </div> </div> </div>		...	<div> <div>No marine fossils.</div> <div> <div>Chikiala sandstones</div> <div>Kota and Maleribeds.</div> </div> </div>
	Rajmahal ...	Golapilly sandstones	Sironcha sandstones	Sironcha sandstones.
LOWER GOND- WANAS.	<div> <div>Kamthi ...</div> <div> <div>Dumapett</div> <div>Chintalpoody</div> </div> </div>	<div> <div>„</div> <div>„</div> </div>	<div> <div>Lingagudium</div> <div>?Tacherla</div> </div>	<div> <div>„</div> <div>„</div> </div>
	...	Barakars	Barakars	Barakars.
	...	Talchirs	Talchirs	Talchirs.

The Talchirs show here as everywhere else the same lithological characters. Above them follow the Barakars, coarse sandstones with very few coal seams, which have a strong lithological resemblance to the equivalent deposits in other basins. The Kamthis are the first to show a differentiated development.

The Chintalpoody sandstones are rather fine-grained, and variegated in red, brown and violet colors; the Dumapett sandstones, on the contrary, are coarser and less iron-stained. They include rather large clay galls with plant-remains. The Tacherla sandstones are chiefly brownish or reddish, but their position is still somewhat uncertain.

With the Sironcha sandstones we enter the region of the Upper Gondwanas. They are grey and brown highly micaceous sandstones, over which come conglomerates and, finally, slaty brownish-grey, violet and yellow sandstones, with plant-remains. A higher horizon is occupied by the red clays of Maleri, in which have been found *Hyperodapedon*, *Parasuchus*¹, and *Ceratodus hislopianus*, *hunterianus*, *virapa* and *oblongus*, Oldham.² The Kota limestone with remains of *Aechmodus* and *Lepidotus*³ appears to be only a local deposit in the red clays. Hughes and King⁴ have recently also discovered plant-remains in these beds. The Gondwana series is concluded in this province by the Chikiala sandstones, which are composed of brown and red iron-stained sandstones and conglomerates, and show

¹ The new work on the fossils of the Kota-Maleri beds by Egerton and Miall is also unfortunately still inaccessible to me.

² Oldham: Mem. Geol. Surv. of India, I, p. 295.

³ Quart. Journ. Geol. Soc., VII, p. 272; IX, p. 350, &c.

⁴ Hughes: Records Geol. Surv. of India, IX, p. 86.

generally a great likeness to the Tripetty sandstones, but have hitherto yielded no traces of marine organisms.

There remains now but the plant-bearing beds of Sikkim to be mentioned. They are grey sandstones with coal seams which protrude in no great thickness from below the overturned crystalline schists. Though so slightly developed vertically, the beds have yet a considerable horizontal extension, as they follow the foot of the mountains from the eastern boundary of Nepal all through Sikkim.

The age of all the several divisions of the Gondwana system in relation to the scale accepted in Europe was till recently but very approximately determined; and even still, after that so much has been settled by Feistmantel's work on the floras of these deposits, the discussion of this theme cannot yet be regarded as at an end, as, in regard to stratigraphic palæophytology, there has been till now no opportunity for really foundational work.

According to Feistmantel's publications we can set up the following synchronistic table of the divisions of the Gondwana system:—

Europe.	I. Bengal.	II. South Rewah, &c.	III. Satpura.	IV. Godavari.	VII. Sikkim.
Jura ...	...	Jabalpur group	Jabalpur group	Chikiala S. sandstones. Kota and Maleri beds.	
Lias ...	Rajmahal group ...	Atgurb sand-stone.	Mahadeva series. { Bagra group Denwa group Pachmari gr.	Sironcha sandstone. ...	
Keuper ...	Panchet group ...	...	Almod group	Kamthi group	
Bunt-Sand-stein. {	Damuda series. { Raniganj gr. Ironstone shales. Barakar group	Pali group ...	Bijori group	...	Damuda series.
	Talchir group ...	Talchir group	Talchir group	Talchir group	

The period of the Muschelkalk is entirely wanting in this table: what has become of it? Has really every trace disappeared in the Indian Peninsula of the deposits of a period during which a great series of beds was developed in the Himalayas?

It is not my intention to review here all the phases which the views have passed through with reference to the age of the several deposits; this much only appears certain, that the Talchir boulder bed with its glacial blocks must in all

probability be transferred to the end of the palæozoic era, or even possibly into it, and that the youngest plant beds reach up to the time of the Upper Jura. For the latter fact there are positive data, as plant-bearing beds are found in Kachh united with others containing a very rich marine fauna. There is a series of beds 3,600 feet in thickness, which, as I have shown, represent the Jura from the Bathonian to the Portlandian in uninterrupted succession, in which every several bed is characterized by numerous species of Cephalopoda, is succeeded by a series of shales and sandstones with land-plants, also some 3,000 feet thick, which in its turn is overlaid by Aptian beds.¹ There can thus be no doubt about the bathological position of the plant-bearing beds, and their age is thus indirectly fixed, that they must belong to the uppermost divisions of the juras or the lowest divisions of the cretaceous system. Dr. Feistmantel has recently endeavoured to settle the age of these plant beds directly, by working out the fossil plant-remains, and has arrived at the astonishing result that according to the plant species occurring in them, these beds must be regarded as liassic, or at most as middle jurassic. The age-determinations thus deduced from the marine fossils and the plant-remains do not agree at all, indeed they lead to results of considerable divergence. Each of the two age-determinations is right according to the present position of our knowledge, but which of the two approaches nearest to absolute truth can unfortunately not be decided, as for that purpose we should require to know the laws of development of the vegetable world from step to step as accurately as we know the succession of the marine molluscan fauna. We are here met by a contradiction that will only be solved by time, and perhaps in India.

It is therefore rather difficult to understand that Dr. Feistmantel² should try and minimize the importance of his discovery by taking all imaginable trouble to explain the inadequacy of the Cephalopoda determined by me for the certain determination of the age of the beds, and to show that the remaining mollusca contained in the Oomia beds should be determined as species belonging to the Bath Oolite. The way in which he proceeds to do this shows, indeed, at the first glance, that he can hardly have ever studied and collected jurassic faunas in the field, for by such a proceeding as he applies, it might not be difficult to bring the oolites of Portland Island into the Bathonian group. He overlooks entirely that Mr. Tate, on whom he chiefly supports himself, has fallen into the same error, like the majority of French inquirers, in confounding the facies with the

¹ See on the subject of Stoliczka's labours in this direction,—Blanford: *Records Geol. Surv. of India*, IX, pp. 80, 81.

² Feistmantel: *Records Geol. Surv. of India*, IX, p. 115, &c. *Jahrb. für Min. Geol. u. Petref.* 1877, and elsewhere. Expressions such as, "The Jura of Kachh was previously regarded as lower oolitic (and correctly so), etc," scattered through Feistmantel's letters, can only have been written with the intention, on the one hand, of discrediting Stoliczka's truly admirable surveys and his sub-division of the Kachh Jura, and, on the other hand, of casting doubts on my determination of species, for it is simply impossible that such a number of Kelloway, Oxford, Kimmeridge, and Portland species could, if correctly determined, be found occurring anywhere in the Lower Oolite.

age of the bed. Dr. Feistmantel appears to believe that I worked out the Kachh Cephalopoda without deigning to give a look to the other fossils. But this was not the case; on the contrary, I went over all the remaining shells as well as the corals together with Dr. Stoliczka very closely, and we both came to the same conclusion, that the Gasteropoda, Pelecypoda, Brachiopoda, and Corals fully justified the conclusions on the age of each several bed as deduced from the Cephalopoda.¹ It was not till then that I published, with Dr. Stoliczka's assent, the tabular view given in the introduction to the Cephalopoda.

As far as I can judge, Dr. Feistmantel appears to me to misunderstand, to a certain extent, the great problem which awaits the phytopalæontologist in India, and the solution of which is certainly worthy of great sacrifices. A series of floras has become known in Europe whose relative ages have been determined either by accompanying marine fossils, or by their bathrological positions with reference to beds containing marine shells. But the geological series of these floras is not a continuous one, as in the case of the marine faunas, but a very imperfect one, compiled from different localities. But in India the very contrary is the case. We have here before us a fragment of a very old continent on which, from the end of the palæozoic epoch through all the duration of the mesozoic era, fresh-water deposits containing numerous plant-remains have been left behind, whereby it is possible to trace the changes of the floras from step to step, as has been done in Europe in the case of the marine faunas. Added to this is the fortunate circumstance that the coast lines of this continent are still preserved in very many places, so that carbonaceous beds which give promise of the discovery of plant-remains are often intercalated between the marine deposits. All conditions combine so as possibly to make India a compendium of palæophytology, such as England has become of the palæontology of marine faunas. But an examination of the fossil floras of India should not be begun by calling in question securely settled facts, such as the age-determination of the Kachh beds by means of the 47 European species of Cephalopoda which occur in their appropriate zones; care should rather be taken to bring all imaginable factors into consideration, and to seek to ascertain, by minute personal collection in the several coal basins on the one hand, and by careful examination of the intermediate coaly beds in the marine formations on the other hand, facts which might give safe general foundations for a stratigraphic palæophytology.

I should not have entered so fully upon this point but for the fear that Dr. Feistmantel might, from his position as Palæontologist of the Geological Survey, confuse for ever the palæontology of the marine faunas of India, and thus render this part of the earth's surface inaccessible for really scientific research. I shall, however, not allow myself to express any opinion of Dr. Feistmantel's labour on fossil plants; this may be done by more competent people than myself.

There can be hardly any doubt that all the divisions of the Gondwana system which I have treated of in the foregoing pages owe their origin to inland

¹ As quite correctly supposed by W. T. Blanford, *Records Geol. Surv. of India*, IX, p. 81.

waters;¹ but whether they were deposited by rivers or in lake basins I will leave undecided.

I must still refer briefly to another group of beds not included in the Gondwana system, which also appears to have been formed in inland basins. These are the Lameta beds which were originally united by J. G. Medlicott with lower deposits, but which were shown by W. T. Blanford to be the probable fresh-water equivalent of the Bagh beds. They show the following section at the Lameta Ghât² near Jubbulpoor: At the base lie dark violet or greenish shales, then follows loose greenish sandstone, then concretionary limestone, and finally sandy silicious limestone that forms the most characteristic member of the group. These silicious limestones are to be seen under the basalt at many places in South Rewah and along the lower course of the Nerbudda, but their horizontal extension is always very small.³ They were also shown by Blanford to occur in the neighbourhood of Nagpur,⁴ and appear also elsewhere in the Godavari basin under the basaltic flows. These beds have hitherto yielded hardly anything beside badly preserved reptilian bones.

In the western part of the Khasi hills are coal beds⁵ belonging to the cretaceous period, which may perhaps there also indicate fresh-water deposits of that period.

With the commencement of the tertiary era the geography of the land changes somewhat. Marine beds appear again south of the first crystalline axis of the Himalayas, for the first time since the palæozoic era. They are nummulitic formations of great thickness which follow the south foot of the mountains, but which extend but a short distance eastward beyond the Sutlej. Wynne has already several times pointed out the great petrographical difference between the nummulitic beds in the Himalaya and those outside of it, but no sufficient explanation has yet been offered for this. The Himalayan deposits of the eocene period are remarkable for thick series of dark shales (which often appear metamorphosed into true clay-slates) and grey limestones, the whole system being poor in fossils. These pass upward into bright red sandstones which only in part still appear to be of marine origin, and which may perhaps be preferably assigned to the oligocene. The nummulitic beds which are thus developed have, together with the red sandstones, been recently distinguished as the Sirmur group.⁶ This facies is found westward of the Jumna along the whole south edge

¹ W. T. Blanford, *Mem. Geol. Surv. of India*, IX, p. 322, says expressly: Not a single marine fossil has been found throughout the great plant-bearing series from the Talchir to the Rajmahals, and I cannot help thinking it most probable that all were river deposits; the Talchirs might be lacustrine, etc.

² J. G. Medlicott: *Mem. Geol. Surv. of India*, II, p. 196. See also H. B. Medlicott: *Records Geol. Surv. of India*, V, p. 115.

³ W. T. Blanford: *Mem. Geol. Surv. of India*, IV.

⁴ W. T. Blanford: *Mem. Geol. Surv. of India*, IX, p. 315.

⁵ Oldham: *Mem. Geol. Surv. of India*, I.

⁶ Medlicott: *Records Geol. Surv. of India*, IX.

of the Himalaya, in the Chitta Pahar and the Affridi mountains. South of that in the Salt Range, in the district of the Luni Pathans and in Sindh, light colored limestones and marls with numerous fossils compose the nummulitic formation. A very interesting classification of the tertiary deposits of Sindh has been recently put forward by W. T. Blanford,¹ in which he distinguishes the following groups: 1, the Ranikot group: variegated shales and sandstones, perhaps cretaceous. 2, the Kirthar group (eocene): green clays, then yellow limestones rich in fossils, lastly, massive white and grey limestones with many nummulites and alveolinæ. 3, the Nari group (lower miocene or upper eocene): yellow and brown limestones with *Numm. garanensis*, *N. sublævigatus*, *Orbit. papyracea*; above these thick unfossiliferous sandstones. 4, the Gaj group (miocene): thin-bedded marine limestones, rich in fossils, clays and sandstones without nummulites. 5, Manchhar group (pliocene): clays, sandstones and conglomerates, with a few fragments of bone, overlaid by thick conglomerates.

Extensive nummulitic areas occur in Kachh and Kattiawar, but they require closer examination. Eastward of the Gulf of Cambay, a few small patches of nummulitic rock occur at the mouth of the Taptee river.

Semi-marine eocene beds of very limited extent occur also at the mouth of the Godavari inclosed between basaltic flows.² In 'Farther India' the whole west coast consists of nummulitic beds which extend through Arracan apparently to the Khasi and Garrow hills. The Naga hills appear also to consist in part of these beds, but they are wanting at the southern foot of the Eastern Himalaya.

Deposits from inland waters of eocene age are not as yet certainly known, but some of the intertrappean fresh-water formations may perhaps belong to this period.

The younger tertiaries occupy enormous surfaces on the western side of the peninsula. It is chiefly in the Himalaya that these have been closely studied, and there it was possible to distinguish several groups. In the little map I employ for the whole division the designation best known in Europe, that of the Siwalik beds. They were all deposited in fresh waters, and in age, as in appearance and mode of deposition, cannot be far distant from the Molasse-rocks of Europe. A narrow zone of these beds, which form generally a chain of hills, accompanies the southern foot of the Himalaya along its entire length. They occupy the Rawal Pindi plateau, follow the east foot of the Suliman Range southward, including the hilly tracts between the mountains and the Indus, and appear to form in general throughout the whole vast region of Rajputana the subsoil out of which the blown sands which there cover such great tracts of land are formed. In the east a narrow strip of these rocks shows itself along the northern slope of the Naga hills; and along the lower course of the Irawadi they fill the basin of the river between the western coast ranges and the ranges of primary rocks in the east. In all the above named localities, excepting Rajputana, mammalian remains have been found.

¹ W. T. Blanford: Records Geol. Surv. of India, IX, p. 9.

² Hislop: Quart. Journ. Geol. Soc., London, XVI.

In the Madras region appear tertiary sandstones of uncertain age (Cuddalore and Rajamundry sandstones) which I have ignored in the little map.

To complete the picture of the Indian succession of formations, there remain but a few words to say on the bathrological position of the Deccan trap, which occupies the entire western half of the Indian peninsula proper. There can be no doubt that the volcanic eruptions to which the Deccan trap owes its origin began already with the commencement of the jurassic epoch, as is clearly shown by the alternation of trap flows with plant-bearing sandstones in the Rajmahal hills. The principal period of eruption lay within the cretaceous era, and chiefly about the end of it, as the Bagh beds (Upper Greensand) are covered directly by flows of genuine Deccan trap.¹ In Kachh the basalts rest on aptian beds, and are covered by nummulitics.² In Sindh also they form the lowest exposed rock.³ On the lower Godavari, on the contrary, Hislop⁴ determined certain fossiliferous beds, which are intercalated between the basalts, as lower eocene: finally, the fresh-water shells which have been described from the intertrappean beds of the neighbourhood of Nagpur⁵ have in their general "habitus" a yet far younger stamp. It would appear from all this, that the outbursts of eruptive rock lasted through very long periods, beginning perhaps with the close of the trias period and extending to beyond the eocene period. It is interesting to observe that this period agrees pretty closely with the period of elevation of the southern part of the Himalaya, while its marine deposits, of the period of the later mesozoic formations, disappeared southward of the first crystalline zone, and to the south of the Indian peninsula the outlines of the continent were subjected to constantly progressive changes through extensive irruptions.

I have now sketched in bold outlines the succession of beds composing the Indian continent, with the exception of the glacial formation and alluvium. These two I can pass over with a clear conscience, as they appear of no importance for the purpose of this essay. On the little map I have shown only the alluvia of the Ganges and Brahmaputra; it stands to reason that the other great rivers are accompanied by alluvial formations; many also of the superficial deposits in Rajputana may have to be considered as alluvia, but with regard to the small scale of the map these features could be conveniently left unnoticed. If we look back, the following points may be deduced as chief results of the facts already stated:—

1. In the paleozoic formations the slaty facies with marine fossils occurs only in the north and north-west, in the Himalaya, the Salt Range, the Hindn Kush, and the Suliman Range. Everything else belongs to the sandstone facies and contains no fossils.

¹ Blanford: Mem. Geol. Surv. of India, VI.

² Wynne: Mem. Geol. Surv. of India, IX.

³ W. T. Blanford: Records Geol. Surv. of India, IX, p. 9.

⁴ Hislop: Quart. Journ. Geol. Soc., London, XVI.

⁵ Hislop: Quart. Journ. Geol. Soc., London, XI and XVI.

2. Of the triassic period unequivocal marine beds occur in the Himalaya, but only to the north of the first crystalline zone, in Hazara, in the Salt Range, and in the opposite direction in Burma. All other beds are deposits from inland waters, with numerous plant-remains.

3. Marine beds of the jurassic and of the lower cretaceous periods occur in the Himalaya north of the first crystalline zone, in the Salt Range, in Rajputana, and in Kachh. Sandstones containing marine fossils mixed with plant-remains show themselves to the west and north of Madras and in the lower Godavari valley. The remaining jurassic beds are deposits from inland basins without marine fossils. The basaltic eruptions commence during this period.

4. Marine beds of the upper cretaceous period occur in the Himalaya, and doubtfully in the Salt Range. They occur also in the Suliman Mountains and in Sindh, also in the basin of the Nerbudda, in the neighbourhood of Trichinopoly, and finally in the Khasi hills. All the other cretaceous beds are deposits from inland basins. The basaltic eruptions continue.

5. In the eocene period the marine nummulitic beds extend again from the west as far as the Jumna. They cover the whole of Western India, are indicated at the mouth of the Godavari, extend north-westward up to the Garrow hills, and stretch all through Burma to the mouth of the Irawadi. Of the inland basin deposits only a few of the intertrappean beds can be here included. The basaltic eruptions cease about this period.

6. The Siwalik beds are entirely of fresh-water origin, and marine deposits of this period are known only in Southern Sindh, in the neighbourhood of Kurrachi, and perhaps in Kachh and Kattiawar.

I have endeavoured to represent graphically, on the little map annexed, some of the facts put forward in the above statements, and have indicated by lines the boundaries of the marine deposits of different epochs. On consideration of these boundaries, it will be seen immediately that India is a fragment of a very old continent whose existence extends back into probably palæozoic times, but whose limits varied much at different periods. The most remarkable fact in connection with this is, that during the greater part of the mesozoic period, the first crystalline range of the Himalaya still lay within the boundary of the continent, so that one would be almost inclined to consider this range as the old coast range of the former continent. The same thing holds good with regard to the Arvalis, which also form a dam between the regions of fresh-water and marine depositions.

The extent of the continent was, like its boundaries, a very variable one. Nearly every palæontologist who has studied carefully the geographical distribution of animals will have been led to the conjecture of a once existent great continent in the southern hemisphere of our earth, as many facts can only be tolerably explained by the assumption of such a continent; I need only recall "Lemuria," and H. F. Blanford's "Indo-Oceanic Continent." It has, however, not yet been attempted to connect such a deduction with particular geological facts, but zoo-geographical observations were relied upon in the first place, and the choice of geological arguments was not exactly a very happy one.

Our knowledge of the distribution of facies within the palæozoic formations in southern latitudes is hardly advanced enough to allow us to judge of palæozoic times, or to advocate the existence of a southern continent in the earlier palæozoic epochs; and they are so widely remote from us in time, that one cannot be too careful in regard of a decision in whatever direction it may be, but it cannot be denied that the course of the boundary shown in the little map might possibly point to a southern continent.

With regard to the mesozoic formations, things are in a different position; one moves here already on firmer ground, as neither widely extended metamorphism, nor denudation too greatly advanced by the length of time, hinder the discovery of the probably once existing boundaries.

If we first take the trias into consideration, we must regard all that lies to the south of the boundary shown in the little map as having been a continent at the time of the deposition of the trias. Although so extremely well developed northward of the first crystalline zone in the Himalaya, the trias possesses absolutely no beds that can be regarded as genuine littoral formations. Some of the beds north of the first crystalline zone which Stoliczka regarded as triassic might possibly be viewed as such littoral formations, but in the absence of fossils the supposition has no support. At the present stage of our knowledge the lie of the boundary along the first crystalline zone is the most probable. A steeply sloping coast, and, in consequence of that, but small true littoral deposition, may be regarded as the cause of the want of such deposits; as through the great disturbance of the bedding these deposits were exposed to such extensive destruction by atmospheric agencies, that they are now entirely removed from our observation. The triassic coast line is all the more clearly to be seen in the Salt Range, where, in progressing from east to west, conglomerates and sandstones with pseudomorphs gradually appear, replaced by limestones with marine fossils, but between which intermediate carbonaceous deposits of very uncertain extent are frequently intercalated. To the eastward the marine deposits of the trias appear to be constantly pushed up northward, and the main mass of the Himalaya mountains proper consists of crystalline rocks, in front of which triassic fresh-water beds are deposited to the southward in Sikkim. The boundary line of the continent facing the sea-covered region in the triassic period thus traverses the Salt Range, then it bends northward up to the first crystalline zone of the Himalaya, follows that to the boundary of Nepal, and then trends pretty straightly eastward, following the upper course of the Brahmaputra more or less, and thus cuts the principal ridge of the Himalaya in a nearly diagonal direction. Whether it then runs east and south in Tibet, and thus finally reaches the marine trias beds in Burma, or whether the latter should be brought into connection with the marine trias beds of "Farther India" and the Indian Archipelago, which is more probable, and thus belong to a different marine province from the Himalayan beds, must, for the present, remain undecided. But it is certain that the boundary line indicates the north and east coasts of a continent, on which were deposited the triassic fresh-water beds of the Indian peninsula.

But we must now turn our attention to the formations related to these inland deposits. Oldham¹ had already pointed out that the plant-remains contained in the sandstones of the Gondwana system recall similar remains both in Australia and South Africa, and W. T. Blanford² has called attention to the similarity between the Ecca conglomerate and the Talchir boulder bed. Feistmantel³ has treated most fully of the Australian and African formations with regard to their relation to the Indian beds, and gives several tabular statements for comparison of the two regions. He also prints a letter from the Revd. Mr. Clarke about the Australian carboniferous beds in which the succession of beds is represented as follows:—

UPPER COAL-MEASURES	{	Upper beds of Tasmania, Queensland and Victoria.
		Clarence river, Wiananatta and Hawkesbury beds.
		Upper beds in the Newcastle Coal-fields, Bowenfels.
LOWER COAL-MEASURES	{	Marine beds (mountain limestone fauna)
		Coal-measures, with plants, of Rix Creek, Stony Creek, Greta, Mount Wingen, &c. (Plants of mesozoic type).
		Marine beds, plants of Smith's Creek, Pt. Stephen's (Mountain-limestone fauna, coal plants).
		Goonoo-Goonoo.
		Devonian.

Of these beds Feistmantel will only allow the upper coal-measures to be regarded as equivalents of the Indian Damuda series; but the reason is not made quite clear in his statements. This, however, affects the matter but little; the chief object is, for the present, to lay stress on the fact that beds have been discovered in Australia which contain a flora similar to that of the Damuda formation.

The agreement between India and Africa appears to be yet greater. Two formations have been distinguished in the latter country, the Karoo and Uitenhague formations. Only the first of these has to be considered with reference to the Indian triassic deposits. It has been divided into—

Sternberg beds,
Beaufort beds,
Koonap beds,
Ecca conglomerate.

Blanford has already called attention to the resemblances of this last division to the Talchir boulder-bed; the third has as yet yielded no fossils; so only the two upper divisions remain for palæontological comparison. They are the beds which yielded those remarkable saurian remains described by Owen, amongst which the Dicynodonts are specially noteworthy. With them plant-remains

¹ Oldham: Mem. Geol. Surv. of India, II.

² W. T. Blanford: Mem. Geol. Surv. of India, IX, p. 325.

³ Feistmantel, in an essay in German, apparently published in Calcutta, but without the name of the place of publication, or of the printer, or date of publication.

were also found in the Beaufort beds, which plants agree very closely with the Indian species of the Damuda series.

Through this great relationship of the plant-remains in the rocks of Africa, India and Australia, H. Blanford was led to suppose the existence of a great continent, which occupied the greatest part of the Indian Ocean, and United Australia, India and Africa, and whose northern coast we have just been trying to trace in the Himalaya. A union of this continent even with China would appear to have existed through Sikkim. To the south, Madagascar and the Mascarene islands were also very probably included in this continent. It is extremely probable that towards the close of the palæozoic epoch the greater part of this continent rose above the sea, and the migration of the flora seems to have proceeded from Australia, as the appearance of *Glossopteris* successively in higher beds as one travels westward also appears to indicate. The glacial periods indicated by the Talchir boulder-bed and the Ecra conglomerate may have offered a barrier to the rapid advance of the flora.

In the jurassic period we meet with totally different circumstances. The coast line of this period is also entirely wanting in the Himalaya, and we can only conjecture from the absence of marine jurassic formations, south of the first crystalline zone, that the former distribution of land and water held good eastward of the Jhilum as well as in the neighbourhood of Katmandu, in Nepal, and in Sikkim. In the Salt Range again the coast line is all the more distinct. The upper beds of the trias and the lower beds of the jura are here developed as such absolutely littoral formations (sandstones with obscure plant-remains and a few littoral gasteropods and bivalves) that it is extremely difficult to determine their age according to the fossils. Only the higher divisions of the jura show really marine formations, but they are still always of littoral type. To the southward of the Salt Range jurassic beds rise up above the desert sand at Jessulmeer. They are sandstones containing Cephalopoda and fragments of fossil wood, and show themselves thus to be littoral formations. The jurassics of Kachh are also littoral throughout, for numerous pieces of petrified wood and other obscure plant-remains are distributed through nearly the whole series of beds, which consists almost entirely of sandstones and shales, and is succeeded above by genuine plant-beds without marine fossils.

The jurassic formations on the lower Godavari, where distinct plant-remains appear mixed with a few marine fossils, were probably deposited at the mouths of rivers. The identity existing between great part of the Godavari species and the Kachh species appears to point to a geographical connection between the two regions. All the other jurassic deposits of the Indian peninsula are fresh-water deposits without marine fossils.

I have drawn the coast line in the little map as based on the facts. According to this, the connection with South Africa which I advocate for the triassic period has completely disappeared in the jurassic period. The Indian continent terminated southward with Ceylon, but in the east it was probably connected with a still larger continent.

If we look at the distribution of the marine jurassic deposits on the east coast of Africa, we shall see at once that the connection of the Indian continent with the African one had ceased. It is very pleasing to see how soon my conjecture that the jurassic sea extended westward from Kachh and reached Africa has been confirmed, Beyrich having described a rich Cephalopodous fauna from the neighbourhood of Mombas, which allows of an exact recognition of the horizon of the Katrol sandstones.¹ Even the quality of the rock consisting of richly ferruginous geodes, less sandy than those in Kachh, which enclose the fossils, is alike.

There can also be hardly any doubt that the marine jurassics forming in South Africa the upper division of the Uitenhague group should be correlated with the Kachh-Oomia beds. The underlying Geelhoutboom beds enclose jurassic plant-remains, which are, according to Feistmantel, nearly related to the Rajmahal fossils, yet differ so much that a more complete geographical separation of the two provinces may be thereby indicated. To regard the Trigonina beds, with Tate, as lower oolitic, or bathonian, will, after the discoveries made in Kachh, hardly enter into the mind of a geologist experienced in the jurassic rocks.

The occurrence of jurassic beds in Madagascar is interesting for the determination of the distribution of the sea during the jurassic epoch. They are deposited against and to westward of older rocks, and thus indicate probably the western coast of a continent of which Madagascar, and possibly also the Mascarene islands are remaining fragments. It was the remainder of the old triassic continent, probably still of great extent, but having become insular already in the jurassic period, for to the eastward we again meet with jurassic marine beds on the western coast of Australia.²

To the north-eastward the Indian continent was apparently connected with China and "Farther India," but we must wait for further information about these regions from Richthofen.

The lower cretaceous accords in its distribution closely with the upper jura, for which reason I have not shown them separately on the map. The upper cretaceous first shows a distinctly different geographical distribution, and must therefore be considered separately. In the north, owing to the want of distinctly littoral deposits, the extent of the former cretaceous can only be determined by the presence or absence of marine deposits. Supported by such rather indirect reasons, I have laid down the marine boundary of the upper cretaceous as running through north-west India, but perhaps in reality it extends much further west through Beluchistan. The Bagh beds in the Nerbudda region are, on the contrary, true littoral formations; a few Echinoderms, Oysters, and Bryozoa tenant the thin deposits. Whether these Bagh beds were directly connected round Ceylon with the cretaceous beds in Trichinopoly district, or

¹ Beyrich: Sitzungsber. Acad. d. W. Berlin, 1877, p. 96.

² The figures given by Moore (Quart. Journ. Geol. Soc., London, XXVI, 226,) of the fossils of this jurassic region are unfortunately so indistinct that no opinion can be formed about the several species.

whether the connexion with Madagascar and the Mascarene islands was again restored in the cretaceous period, can at present hardly be decided. We have certainly got excellent littoral formations in the South Indian cretaceous beds which contain even land shells (*Helicidae*). The cretaceous beds of the Garrow hills show the same development, and it cannot be doubted that they were connected with the Trichinopoly beds. It appears equally certain that the South African cretaceous beds described by Griesbach¹ owed their origin to the same marine basin as did the South Indian beds. We have therefore certain east and west coasts of the Indian continent in the cretaceous periods, and the north coast also will not require to be greatly changed; the south coast, on the contrary, is uncertain, but I have inserted it similarly to the jurassic coast line as questionable.

The extension of the eocene sea in India was similar to that of the cretaceous sea; it was only to the west that the sea penetrated far inland; but how far the continent may have extended to the south at this period is still quite uncertain.

After the conclusion of the eocene epoch, the sea retreated altogether from India; only in the neighbourhood of Karachi and Arracan does it appear to have touched the Indian continent, so that the sea of the miocene and pliocene periods probably extended away to the southward. On the other hand, a north-westerly connection of the continents probably took place with North Africa through Arabia, as has been already assumed by Huxley.

If we look back once more, we find that the simple facts of the geographical distribution of the formations, and the formational facies in India, allow of obtaining deep insight into the changeful history of the distribution of land and water through long periods and over a great part of the southern hemisphere of our earth, as India participated in all the changes, and always formed part of the great southern continent which was so often broken up and then re-connected. I have in my deductions purposely left out of consideration the geographical distribution of the fauna and flora of the present world-epoch, as I wished to move on purely geologico-palæontological ground. It may remain for other searchers to decide how far my deductions agree with those obtained from the zoö- or phyto-geographic facts. This much, however, is certain, that H. Blanford's supposition of an Indo-Oceanic continent that united Africa, India and Australia, and existed with few interruptions and without important changes from the end of the palæozoic up to the miocene and pliocene periods, is thoroughly erroneous, and that such assumption is not justified by the geographical distribution of the marine deposits either in India or any other part of the world.

How far the Indian continent as now established has in the course of ages been related to the great mountain formations to the east, north, and west as a block (*Festlandsscholle*), according to Süss's meaning, I hope perhaps to be able to show in another essay.

EXPLANATION OF THE MAP.

Although the map may to a certain extent be understood from what has been said above, it may not be superfluous again to emphasize those points which

¹ Quart. Journ. Geol. Soc., XXVII, p. 53.

demand closer consideration in order to appreciate justly what it has been attempted to represent. Above all, it cannot be pointed out too frequently that the map, although intended to give a general picture of the distribution of the formations in India, has been constructed for the special purpose of showing the distribution of the sea and the continents during the mesozoic period, and that for this reason a number of the younger superficial formations have been omitted entirely, specially all alluvia (with exception of the abnormally extensive alluvia of the Ganges and Brahmaputra), also the laterite, which is developed to such great thickness and extent, and further the mammaliferous gravels of the Deccan, and the Cuddalore sandstone, etc. The eruptive formations, excepting the so-called Deccan trap, have been everywhere neglected; and even the small outlier of Deccan trap which in Rajahmundry district encloses brackish water nummulitic beds and rests itself upon presumably cretaceous rocks, had to be omitted because of the small scale of the little map. The great space indicating the wide extension of the Siwalik beds in and to the north of the Rajputana desert is intended more to point out the probable once existing extension of the fresh-water lake in which those beds were deposited than to show the outcrop of rocks actually observed, as no reliable observations were available from this part of India.

The two types of development existing within the limits of the mesozoic deposits have been indicated by stippling, in order to show at a single glance the distribution of the marine formations and the deposits formed in inland basins.

A similar distinction has been applied to the palæozoic formations, without wishing, however, to distinguish positively here between marine and inland-water beds.

The crystalline formations shown in the map include probably a great period of time, and the boundary between them and the palæozoic beds is very fluctuating, so that many of the formations on the boundary are locally reckoned sometimes to the former, sometimes to the latter series. According to the accounts now existing, it is hardly possible here to draw the boundary adequately in every case.

The continental boundaries laid down with dotted and broken lines have been explained sufficiently in the foregoing pages.

We may now expect soon to receive further details bearing on the geological representation of India from W. T. Blanford's official map of India, which is now in the press. I wish further only to remark that this essay with its map had been completed by me long before I received the first tidings of Blanford's intended publication, and that its presentation to the Imperial Academy of Science was only delayed by circumstances which it was not in my power to control.

SUBMERGED FOREST ON BOMBAY ISLAND. *Observations by G. E. ORMISTON, Resident Engineer, Bombay Port Trust, dated 29th May 1878 (communicated by Government).*

The strata exposed in the excavation for the Prince's Dock consist of the surface silt or black mud, which overlies to a depth of from 4 to 5 feet a dense blue clay of varying thickness (from 6 to 20 feet), but nearly level on top; underneath this is found loam, moorum¹, and rock; the latter is very irregular on the surface, running at times into long narrow ridges and masses of boulders with soil between. The rock is soft, and consists mostly of indurated clay nodules imbedded in a hard matrix. Numbers of trees have been found (about 260 up to date). Many had been overturned before being covered with the blue clay, but the roots were only partially torn out of the loam or moorum in which they grew, others were standing upright with their roots deeply planted in their native soil. The standing trees only extend to the surface of the blue clay, none penetrated the muddy silt above; and for a foot or so below the level of the blue clay, the timber was riddled by the *Teredo navalis*, or a similarly destructive worm. Most of the other trees also showed signs of this worm. One tree was found charred on one side for a short distance. The largest trunk found was 46 feet long and 4 feet 8 inches in girth; some of the timber is quite sound; it is of the colour of dark rose-wood, and with a straight grain. The level of the roots of these varied from low-water extreme spring tides to 12 feet under. This shows the land to have subsided at least 30 feet, as the trees must have grown above high-water mark.

NOTE.—This discovery of trees, in the spot on which they grew, below low-water mark in Bombay Island is chiefly remarkable, because it shews that, in recent or sub-recent times, depression must have taken place in the immediate neighbourhood of ground which appears to have been raised. The Prince's Dock is on the eastern or harbour side of Bombay Island, and the Esplanade surrounding the fort on the western side, not a mile away from the dock, is composed of the rock called littoral concrete by Dr. Buist, a mass of shells, corals and sand cemented together by carbonate of lime. It is scarcely possible that the materials of which this rock consists can have been accumulated at their present elevation above the sea; in all probability they formed, when first deposited, a sand bank or beach not raised above high-water mark, and as it is difficult to understand how elevation and depression can have occurred simultaneously on different sides of so small an area as Bombay Island, it is probable that the whole area has undergone elevation and depression alternately. If the elevation be the older movement, then the Esplanade must once have been several feet higher than it now is; if the depression is older, the trees at Prince's Dock have been at a greater depth beneath the sea than they now are. The former is perhaps more probable.

That such alternate movements of elevation and depression have taken place in Bombay Island was shewn by Dr. Buist² many years ago, though to a smaller extent than now appears probable. At the same time, before the depth to which depression has extended in this case can be estimated, it is necessary to ascertain what kinds of trees are represented. If they be such as grow on land, the depression must have been greater than if they belong to such forms as *Avicennia* or *Bruguiera*, which grow some feet below high-water mark. The circumstance that the trees are bored by *Teredo* is in favour of their having grown in salt marsh, where these mollusca are peculiarly abundant.

W. T. BLANFORD.

¹ A local term for decomposed rock.

² Transactions of the Bombay Geographical Society, Vol. X, p. 177, 1857.

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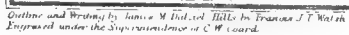
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Compiled by J O N Jarvis

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.]

1879.

[February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1878.

• In the report for a year that has been comparatively unproductive of fresh work, I have to record, as compensation, the completion of the Manual of the Geology of India. The two facts are, indeed, closely connected: The Manual is principally—readers will often find cause to regret that it is not all—the work of Mr. Blanford, who was thereby prevented from taking the field in the open season of 1877-78. When results are to be measured by the knowledge gained from the study of obscure facts, many circumstances affect the tale of progress, which depends more upon the study than upon the accumulation of what are called observations. Geology has suffered much from the delusion that the two offices can be separated.

The Manual itself is a progress report *in extenso*—a full summary both of what is known and of what we fancy to be known regarding the geology of India, *i.e.*; of supposed (partial) facts, and of the apparent conclusions therefrom. Despite explanation and cautions given, students are likely to forget the very scanty and crude state of the information upon which much of the work is based, and therefore how liable to overthrow are the inferences suggested from that information. Such inferences have been freely offered in the Manual, in order to give point to the description, and to incite other observers with the agreeable encouragement of discovering error. Now that a more intelligent understanding is gaining ground regarding scientific method, the rational use of hypothesis as opposed to dogma, it is possible to be instructive without misleading others or stultifying one's self. Unfortunately, our work in India still suffers from the impunity with which either blunder might be committed; as the business of correction and exposure is almost entirely in our own hands. The duty of self-correction will not, however, be lost sight of, or evaded. The Manual affords an excellent datum-line, available to all, from which to mark the phases of our

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progress, and the annual report is the appropriate medium for bringing to notice such changes as have become necessary in the provisional interpretations of that date. Already, almost coterminously with the publication of the Manual, the balance of evidence on some points has been affected by the results of the last season's work, as will be mentioned in the following remarks.

Before alluding to this work of detail, I would make mention of some general observations on the geology of India published within the year, and based upon the work of the Survey. Our distinguished colleague, Dr. Waagen, whose services, I am happy to say, are still engaged in our behalf, so far as his health will permit, presented to the Academy of Vienna a sketch of the geology of India based upon a discussion of its palaeontology. Work of this kind is of the highest value and interest, as representing the results and the rationale of the details of palaeontological research. For the benefit of English students, in India or elsewhere, a translation of the paper is published in the Records for November.

So far as relates immediately to India, the features evolved are of permanent importance. The only misgiving that occurs to one in respect of the wider generalizations is, that the provisional condition of the biological principles upon which most of these deductions depend may not have been sufficiently kept in view. Several relations in the comparative palaeogeography of very distant countries are confidently assigned, on the assumption of certain laws of distribution of life, in time and space. Now, however confident we may feel regarding the general principle of the derivation of organic forms, the particular view of that principle necessary to the validity of such speculations as those under notice is still under discussion, and the familiar application of it, as if established, may (or even must) seriously interfere with the verification and study of the great biological problem which is the highest object of geological pursuit, and as subsidiary to which these geographical puzzles are principally of any interest. To those who are awake to the importance of the vital question, even though they may not be qualified to discuss it directly, such interference is a subject of regret.

In the last presidential address to the Geological Society of London, Professor Martin Duncan gives a most instructive review of many complicated problems in zoology and palaeontology. From his statement of the objections to accepting the relative classification of the tertiary rocks of India, as recently put forward by the Survey, it might be thought that some decidedly unscientific prejudice had had influence in the discussion. Objections are of more service to us than approval, and some of those made by this high authority may not be so easily removed as the one I have mentioned. With the greatest respect for the work of the illustrious Falconer, of whom we are most justly proud as the local founder of palaeontological research, it was not thought that his views could be final, or that they were compatible with a fuller knowledge of the formations. He had treated as one fauna the fossils from a prodigious series of strata, in which those fossils are by no means promiscuously distributed. It did not seem even that Falconer himself had considered his opinion conclusive on these points of correlation, more especially as regards the older gravels of the Indian river valleys.

When, therefore, a stone implement was found in these gravels, it was made the occasion of a special consideration of some features of the case that had not previously been discussed. This proceeding was no more than was demanded by the peculiar interest of the occasion. The same judicious caution has markedly characterized the most recent investigations by perfectly impartial observers regarding the human period in England.

Peninsular area : Azoic rocks.—To follow the order observed in the Manual, the azoic rocks are noticed first. The Arvali region is the only ground where we have been especially engaged upon these formations during the past season. Mr. Hacket examined a very large area at the northern extremity of the range, with all the outliers between Deeg and Toshám (near Hânsi), up to the Jumna at Delhi. Mr. Hacket has hitherto had this area all to himself, and at pages 48 to 52 of the Manual an abstract is given of the provisional views then suggested. Very considerable changes in the stratigraphical series are now proposed. The Mandan and Ajabgarh groups, lying mainly to the west of the Alwar and Delhi range of quartzites, were placed at the top of the series. The Mandan rocks occur in isolated ridges, and were separated from the Ajabgarh beds on account of the absence of certain bands that are prominent in the latter group; while the Ajabgarh beds were placed above the Alwar quartzites on account of some cases of steep, partial superposition which must now be regarded as inversions, for Mr. Hacket considers both the Mandan and Ajabgarh beds to be representative of the Raiáo group, underlying the Alwar quartzites. In the study of extensive areas of contorted transition rocks, the tendency is usually towards a greater subdivision and expansion of the series, original features of unconformity being often disguised by the crushing of the strata; but Mr. Hacket makes out a good case for this contraction of the Arvali series, as first proposed. The very mixed and variable character of the deposits of the Raiáo group was pointed out from the first; and in this as well as in other petrological characters the agreement of the Mandan and Ajabgarh rocks is sufficiently close, besides that new sections have shown these to have the same relation as the Raiáos to the gneiss and to the Alwar quartzites.

The adoption of two instead of four groups is, so far, an apparent simplification; but the chief structural difficulties of the ground are still unexplained. These are, the almost incompatible variations in the relations of these groups to each other and to the gneiss. In many sections the two groups are described as completely transitional, by interstratification. Again, each group is locally described as transitional with the gneiss: the Raiáo black slates passing down into a dark schistose gneiss; and the Alwar quartzites being transitional downwards with a gneiss that is only a subfoliated feldspathic quartzite. But in other sections the Alwar quartzite is described as overlapping on gneiss, as in the hills between Udepur and Khandela, 40 miles north-west of Jeypore. These discrepancies might be got over by assuming that all the gneiss is simply converted Arvali strata, the metamorphism having extended locally to different horizons; and that the word 'overlap' is misapplied in such cases, for it implies a primitive gneiss, with original local absence of the Raiáo group; and no distinction of gneisses has been

attempted. This easy solution of the difficulty might be adopted, were it not that other observations independently require such original conditions as are implied by overlap: in the little hills south of the railway between the Basi and Jatwára stations, 20 miles east of Jeypore, a coarse conglomerate occurs at the junction of the Alwar and Raiáo groups, containing large boulders of gneiss, quartzite, limestone, and of a banded jaspideous rock, in a schistose matrix. Now, it seems impossible, under any recognized doctrines of rock-formation, to consider such debris as this to be derived from the series in which it occurs; and the gneiss boulders especially require the supposition of a metamorphic series older than that of the Arvalis themselves, and upon which an overlap of the Alwar quartzites might naturally occur. But no such rocks have been discriminated within the very large area of these formations explored. Should this stratigraphical evidence fail, it may be permissible to suggest some primitive conditions of rock-formation, involving some very rapid process of induration of deposits, or even their crystallization, to take the place of what is commonly implied by metamorphism; and also involving much greater facilities of very local disturbance, whereby the same deposits may be strongly unconformable and in unbroken sequence, within close proximity. The proved extreme antiquity of the transition rocks of the Indian Peninsula admits, perhaps, of some appeal to conditions differing widely from any standard of processes now in operation. These rocks may, indeed, be azoic in the original acceptation of the term—*anterior to the appearance of life in this portion of the earth's surface.*

The foregoing remarks refer only to the Arvali rocks, as hitherto described; but Mr. Hacket's observations of last season lead him to extend these views to some rocks of the adjoining region to the east, although without a re-examination of these sections. The change offers an immediate relief from the difficulties stated on pages 51 and 52 of the Manual. At the eastern edge of the Arvali region, close along the scarp of the Vindhyan series, there appear in the Hindaun ridge some typical representatives of the Gwalior series. In their standard area, to the east of the Vindhyan basin, these rocks rest, undisturbed and completely unconformable, upon the gneiss of Bundelkhand; and the puzzle was to find a place for these Gwaliors of the Hindaun ridge, either between the Vindhyan and the Arvali series, or between these and the Arvali gneiss; the former alternative being provisionally accepted as the least anomalous. It was thought that the peculiar composition of the Gwalior rocks and their local unconformity to the Arvali series forbade their being identified with this series. Now, however, Mr. Hacket considers that, as with the Mandan and Ajabgarh groups, so the Gwalior rocks must be brought within the horizon of the Raiáo group, and for similar reasons. The most peculiar and prevailing character of the Gwalior series is the presence of jaspideous bands, generally of a bright red colour. The very special nature of this rock, however abundant locally, would be in itself an excuse for not insisting upon it as a character of wide extension. The objection is, moreover, modified by the occurrence of compact silicious bands in the Raiáo group, as in the hills near Sathána in Shaikhawáti; near Chenpura, north-east of Basi railway station; and near Muhammadpur, south of Kherli station.

The Gwalior rocks have been independently ranked as in the upper transition series of Peninsular India, as probably equivalent to the Kadapah series of Southern India; and thus the Arvali series, in great part metamorphic, would be brought into a more defined position in the general scale of Indian formations.

Gondwána rocks: Palamow.—On page 198 of the Manual mere mention could be made of the 'unsurveyed basins of Palamow.' A description of these coal-fields by Mr. Ball, with maps, has since been published (Mem. G. S. I., Vol. XV, pt. 1). This ground is more accessible from the trunk railway than the coal-basins of the upper Damuda valley; and projects for working the coal have lately been proposed. Two new coal-fields have been marked in the basin of the Koel river: the Aurunga field on the east has an area of 97 square miles; and the Hutár field on the west, traversed by the river Koel, has an area of 78 square miles. Both measurements include the whole of the Gondwána deposits, but the areas to be deducted from the Talchir outcrop are small. So far as could be determined from surface indications, the coal of these areas, especially in the Aurunga field, is not so good as that of the smaller Daltonganj field, lower down the Koel, to the north.

The geological interest of this ground is, that here a marked change takes place in the petrological characters of the Gondwána system, between the series as developed in the Damuda valley coal-fields and that found in the great midland area of South Rewah (the Son region), as well as in the Mahánadi and Godávari regions. In the Damuda region three considerable deposits (the Ironstone Shales, Rániganj, and Panchet groups), of lower Gondwána age, are petrologically well distinguished from the lower coal-measures (Barákar group). These groups are here overlaid by a thick sandstone, generally characterized by its comparative want of earthy bond, and its consequent porosity. It was originally named the upper Panchet group, in the Rániganj field; but from its presumable equivalence to the Dubrájpur sandstone of the Rájmahál region, in which upper Gondwána fossils occur, and from partial unconformity, it has latterly been separated from the lower Gondwána series, under the general name 'Mahádeva,' which is at present a partial equivalent for upper Gondwána. In the midland and south-eastern regions a sandstone of this type rests immediately upon beds representing the lower coal-measures of Bengal, and overlap-unconformity is at many places very marked at this horizon. Notwithstanding these marks of changed conditions, it appears from the fossils that a great thickness of these upper sandstones (Kámthi) in the Godávari valley must be recognized as lower Gondwánas, possibly on the horizon of the Rániganj group of the Damuda fields.

Mr. Ball established the same fact for the upper sandstones at Hengir in the Mahánadi region; and he now (*l. c.*, p. 46) confirms the observation of the strong resemblance between that rock and the sandstone resting on the lower coal-measures in Western Palamow, but which he shows to be unquestionably identical stratigraphically with the supra-Panchet sandstone of the Damuda area. Upon this the suggestion is made that the Hengir rocks present a blending of the characteristics of two groups, which in Palamow are separated by a distinct

interval. Of such distinct interval, however, no more direct stratigraphical evidence is found in Palamow than elsewhere, beyond the original fact of the intercalation of deposits not found away from the Damuda area: the apparent sequence of the upper sandstone (Mahádeva of Mr. Ball's report) on the Barákars here being at least as regular as in the south-eastern Gondwána regions; so that the expectation to find lower Gondwána fossils in this rock here would still be justified. Thus, the question stands pretty much as before, save that we know exactly where this change of petrological characters takes place.

It had been surmised that this change would coincide with the limits of the Damuda valley; but Mr. Ball has found that it is not so. A barrier of gneiss, between the Kárunpura and Aurunga coal-basins, divides the waters of the Damuda and the Aurunga, which is a tributary of the Koel; and in the eastern part of the Aurunga field the Panchet and Rániganj groups are about as well developed as in the Kárunpura field, their combined thickness being about 1,700 feet, and they are covered by the upper sandstone. Notwithstanding this great development in thickness, the extension of these two lower Gondwána groups is strangely limited. The feature under notice is, indeed, brought within a compass of two miles in the hills south of Latehár, at the west end of which the upper (Mahádeva) sandstone rests on Barákars, and at the east end on Panchets. Both the north and south boundaries are represented as faulted, so that the overlap cannot be followed out; but this case gives at least the assurance that the covering sandstone, so differently circumstanced at its base, is one and the same formation. The absence of fossils in these sections is deplorable. Without them the position of this top sandstone in the general series must remain doubtful: in the west of the Aurunga field its relation to the coal-measures is precisely like that of the Kámthi and Hengir rocks to the similar coal-measures of the Godávari and Mahánadi regions, while in the eastern part of the field it overlies beds (Panchets), which in turn overlie those (Rániganj) that have been correlated with the Kámthis.

The gneissic barrier between the Aurunga and Kárunpura fields being much higher relatively to the former than to the latter, Mr. Ball considers that the separation is due to disturbance, by a sinking of the Aurunga basin; so that they may still be virtually considered as belonging to the same original area, and the similarity of the sections be attributed to some peculiar conditions of that ground.

In the Son region, shortly to the west of Palamow, the upper sandstone series becomes enormously expanded; and if, as seems probable, this rock in Palamow represents the base of that expanded series, which, again, in its southern extension is likely to be identified with the Kámthi beds of Hengir, then the top sandstone of the Damuda region cannot properly be classed as upper Gondwána (Mahádeva), or identified with the Dubrájpur group of the Rájmahál region; nor could the Kámthis then be properly correlated with the Rániganj group, unless a certain correspondence of the fossil floras at distant localities is to set aside local superposition in the Damuda region, represented elsewhere by the most clearly and most widely marked stratigraphical change in the whole Gondwána series.

It is independently a most puzzling circumstance, how such great overlap, as that described within the sedimentary series in the Aurunga basin, can be attended by so little evidence of unconformity in adjoining ground. Mr. Ball's supposition that much disturbance and denudation, whereby the chain of coal-basins of the Damuda valley were defined, and whereby the deposition of the upper sandstone was limited to that depression, intervened before the deposition of the upper sandstone, almost increases the difficulties of the case in the absence of any evidence for such unconformity as must have attended that event.

The most distinct case of apparent disturbance-unconformity observed by Mr. Ball (*l. c.*, p. 87) is between the upper sandstone and the Panchets, not between it and the lower coal-measures. It is still an open question whether the apparent anomalies of these sections may not be largely traced to original (pre-Gondwána) conditions of the surface.

Godávari region.—From the foregoing remarks it will be understood that the distinction of upper and lower Gondwána rocks in the Damuda region is still presumptive, based principally on the supposed equivalence of the top sandstone of the series with the undoubted upper Gondwána sandstone of the detached area to the north-east, in the Rájmahál hills, and upon occasional cases of overlap-unconformity in the Damuda coal-fields. But similar unconformity and great irregularity occurs also in the upper groups of the recognized lower Gondwánas of the Damuda region; while the most marked lithological change and overlap-unconformity in the midland and southern Gondwána regions is found within the lower Gondwána series, between the coal-measures and the Kámthi-Hengir sandstones, which in this direction present the most marked analogue of the top sandstone of Palamow.

In the Godávari region the fixing of this middle Gondwána horizon has been for some time, and is still, a great puzzle. On the lower Godávari it seemed to be made out by Mr. King, between the local representatives of the Kámthi group and the Golapilli sandstones, containing a Rájmahál flora; and Mr. King thought he identified this group on the Pránhita, just above its confluence with the Godávari, in the sandstone of Sironcha, having found Golapilli fossils in what he took to be a top band of this sandstone at Anáram, near Kota, not far below the well known *Lepidotus* limestone of that place (*Rec. G. S. I.*, Vol. X, p. 55).

Working from the north, Mr. Hughes found no upper Gondwána rocks in the Wardha coal-basin, but at the southern edge of that area, on the lower Wardha, about Porsa, the Kámthis are overlaid by red clays, which are identified with the well known *Ceratodus* clays of Maleri. This formation spreads rapidly to the south. It is locally covered on the east by the plateau-forming conglomeratic sandstones of Chikiála, resting against Vindhyan rocks; and to the west it extends far up the Jangaon valley, gradually overlapping the Kámthi strata, so as to rest against Vindhyan, and then passes under the Deccan trap. Here, too, plant fossils of decided upper Gondwána type were found, so that on this cross-section the whole Gondwána area, 50 miles wide, is occupied by well

marked upper Gondwána strata. South of the Jangaon valley the Kámthis emerge again in force, encroaching upon the upper rocks up to Sironcha, where the latter are reduced to a width of six miles. Mr. Hughes carried his lines up to the Godávári and the Pránhita at Sironcha, recognizing no group between the Kota-Maleris and the Kámthis. Here he encountered Mr. King's Sironcha sandstone, the lithological peculiarities of which he admits, considering it more like the rocks associated with the Maleri clays, than it is like the typical Kámthis (Rec. G. S. I., Vol. XI, p. 23). If, however, this rock, as mapped by Mr. King up to the Godávári from the south, is to be taken in this light, or as a group distinct from both Maleris and Kámthis, or, as would appear on Mr. Hughes' map, in great part as a peculiar form of the upper Kámthis, a part of the ground mapped north of the Godávári will have to be modified accordingly.

Mr. King's observations of last season are still conflicting as to which of these views may prove true. He finds the conglomeratic sandstone of Anáram, with which the upper Gondwána fossils occur, to be local, and considers it more likely to be a local deposit, or a remnant of an overlying formation, than to belong to the underlying Sironcha sandstone. Again, he describes regular Sironcha sandstone as unconformably overlaid by the reptilian clays of the Agrezpali outlier, on the Godávári, 16 miles above Sironcha. Mr. Hughes thought these clays might be high in the Kota-Maleri group; but Mr. King does not adopt this suggestion, and considers them on the horizon of the beds at Maleri. Thus, these two observations are strongly suggestive of the Sironcha being lower Gondwána, either as upper Kámthis, or as an independent group.

On the other hand, Mr. King is in favour of a division of the Kota-Maleri group, as he finds that its upper portion only, at and above the horizon of the Kota limestone, is represented in the prolongation of that formation south-east of the Pránhita, overlying, if not faulted against, the Sironcha sandstone. Such an overlap would be valid ground for reviving the original question of the probably marked separation of the *Lepidotus* limestone and the *Ceratodus* clays. In this connexion Mr. Hughes' partial identification of the Sironcha sandstone with that associated with the Maleri clay (Rec. G. S. I., Vol. XI, p. 23) is suggestive of the possibility that these two rocks are locally representatives of each other. In this case the views given in the preceding paragraph would require modification: the search for the middle Gondwána horizon would have to be taken up again, even in the Kota-Maleri area; involving the reinvestigation of the horizon of the plant beds in the Jangaon valley, as to whether they may not be in the upper division of the group, as is indeed suggested by the probable identification of the Chikiála beds at Balánpur. Mr. King hopes to be able to revise, and decide upon, these crucial points during the present season.

Early in the season Dr. Feistmantel visited the Sápura coal-basin, to examine on the ground some good sections of the Gondwána series, the flora of which he has been studying and describing so carefully, and with great advantage to the Survey. The coal-measures of those fields were always taken to represent Barákars, the lowest of the Damuda coal-measures; and Dr. Feistmantel has shown

that they belong rather to that still lower horizon of coal-bearing strata, represented by the Karharbári measures in Bengal.

On the western confines of the Peninsula, where the Gondwánas become associated with marine strata, Mr. Fedden broke new ground in Kattywar. He was detained by office work in Calcutta, in classifying some of the collections made by him in previous years, and arranging them in the new Museum, and he consequently did not take the field till the end of 1877. In the early months of the past year he surveyed a portion of Kattywar, amounting to about 1,800 square miles, comprised in Topographical Survey sheets 21, 22, 23, and portions of some of those adjoining. Mr. Fedden speaks very highly of the excellence of these maps. The country examined is for the most part flat, and the rocks consist of Deccan traps, overlying sandstone, in which some remains of plants were found. These plants prove to be identical with those occurring in the uppermost jurassic or Umia beds of Cutch, and it is thus clear that a portion at least of the Cutch jurassic series extends into Northern Kattywar.

The greater part of the area examined consists of jurassic sandstone, the hills being of trap; but to the southward, where the surface is more hilly, the traps cover the country. The beds, both of sandstone and trap, are nearly horizontal. In some places between the jurassic beds and the traps a thin band of limestone is found, which contains a few obscure marine organisms. This band may perhaps represent the Bágh beds of the Narbada valley. A few intertrappean bands are found, and some outlying patches of milliolite were noticed resting on the trap.

In Southern India Mr. Foote took up new ground to the south of Trichinopoly. In crossing the cretaceous area he made some valuable additions to our fossil collections from those formations. He also re-examined the localities where the Utatúr plant beds occur at the base of the series. He completely identifies them with the jurassic beds containing both plants and marine animal remains, described by himself, at many points along the coastal region up to the Kistna. From the entire similarity of the fossil plants and their mode of preservation to those of the deposits elsewhere in which marine fossils are described in the same beds, Mr. Foote is of opinion that the Utatúr plant beds also are probably marine; in support of which view he mentions his inability to find stratigraphical evidence (more than overlap) of a break between them and the overlying middle cretaceous deposits, thus confirming the previous observation of others upon this interesting point. Mr. Foote's notes upon these features are published in the Records for the year.

The country south of Tanjore has, so far, proved very uninteresting; no rock appearing between the gneiss and the coast alluvium, except the Cuddalore sandstone formation, intimately blended with the covering laterite.

Extra Peninsular area.—In the extreme North-Western Punjab, Mr. Wynne made a preliminary examination of some new ground in Hazára, having been prevented by difficulties on the frontier from following the formations of the Salt Range across the Indus into Bannu, as had been proposed. Owing to the exceptionally wet season, and illness occasioned thereby, the amount and details of the

work are not what Mr. Wynne expected to accomplish; still he has given a most useful reconnoissance of the ground: the limits of the crystalline rocks forming the higher mountains have been defined, and a tentative classification and distribution given of the unaltered sedimentary series to the south of the gneissic area.

The most interesting feature of the observations is the extension to the older rock-series of the contrast which has been known to exist in the newer formations, between the Southern Himalayan area and the country to the west of the Jhelam. In Huzára the rocks adjoining, and apparently in sequence with, the gneissic rocks are a great thickness of sandstones, quartzites, and dolomites, called by Mr. Wynne the 'Tanól series,' presenting little or no correspondence with the strata similarly related to the gneiss of the Pír Panjál. But the most anomalous circumstance is, that Mr. Wynne provisionally identifies the Tanól series with the 'Infra Trias' group of the section in Sirban mountain (west of Abbottabad), which is there distinctly in unconformable superposition on the Attock slates (*see* Manual, p. 499), this relation not being so clearly defined at the junction of these slates with the main area of Tanóls, west of Abbottabad. If these conjectures are confirmed, it would seem that the gneiss of Hazára is much newer than the central gneiss of the Himalayas.

The severe famine in Kashmir interfered much with Mr. Lydekker's work in the North-West Himalayas. This, and a temporary indisposition, prevented his carrying out his projected trip to the Gilgit region; so he spent the season in the mountains of Drás and Tilail, where he has described some important sections of the sedimentary rocks. Mr. Lydekker insists strongly upon the transitional relations of the whole series from silurian to upper triassic (*see* Manual, p. 660).

Colonel McMahon has again made an important contribution to our work in the Himalayan regions—this time in the Central Himalayan districts, to the north of the Simla region of the lower Himalayas. His observations involve a reconsideration of some views provisionally put forward in the Manual, while yielding confirmatory evidence upon others.

The strongly unconformable relation of the limestone and slate series of the lower Himalayas to the central gneiss, presented some difficulty as compared with the pseudo-conformity of the same sedimentary series to this gneiss on the Tibetan side (Manual, p. 679 (*a*)). Colonel McMahon describes this northern junction within four miles of the intrusive granitic mass of Gongra, between Lipe and the Rukhang Pass, as exhibiting an appearance of transitional metamorphism, which contrasts with the more abrupt contact at the Bhabeh Pass and in Niti. Such local action does not, however, disturb the inferences based upon the other sections. On the other hand, he observed in Hangrang, east of the lower Spiti valley, the upper (Muth) beds of the slate series to be in original superposition on gneiss at the base of the Purguil Mountain, the gneiss being, up to the very contact, profusely cut up by large and small granite veins that do not penetrate the overlying limestone and slates, which are not described as more altered than at points remote from the crystalline rock. This would appear to fix a very definite limit as to the age of these granitic veins; and the total overlap of the

great mass of the slate series establishes for this area original conditions of unconformity with the central gneiss, like those already exhibited in the Simla region. The position of this overlap, against the transverse gneissic mass of Purguil, shows, moreover, that this barrier between the Zānskār and Hundes basins is of very old standing, though it may not always (since palæozoic times) have been so prominent as now.

Another important observation of Colonel McMahon's is his reaffirmation of Stoliczka's original identification of the Krol limestone with the Lilang limestone of Spiti. This decided opinion, based upon immediate comparisons of the sections in those adjoining regions, although separated by the great gneissic axis, cannot be set aside; it is at least as valid as the very broken chain of evidence upon which a different correlation was provisionally adopted in the Manual (pp. 595-6). The intimate connexion of the triassic and carboniferous series, as urged by Mr. Lydekker, will, in the absence of fossils, make the close decision of this question a matter of greater difficulty.

Mr. Theobald made large additions during last season to our collections of the Siwalik fauna, the results of which are duly recorded, up to date, in Mr. Lydekker's papers in the Records and the *Palæontologia Indica*. Mr. Theobald is now engaged upon the tertiary zone east of the Ganges in Rohilkhand, at the base of the Himalayas of Garhwāl and Kumaun.

Mr. Mallet was deputed in December to report upon some coal seams in Rāmri Island, reported by the Commissioner of Akyab. Mr. Mallet could not form a favourable opinion of the practical value of these measures; the coal is inferior to that of Bengal, and the measures are greatly disturbed, and would be very difficult to work. Specimens of a very different coal, a bright jetty lignite, were forwarded by the Commissioner from the Barānga Islands. The site of this coal has not yet been discovered; but the fact that the piece sent is distinctly a piece of carbonized wood, suggests the probability that it occurs in isolated logs, and not as a continuous seam. The petroleum of this region seems, so far, to offer more favourable prospects than the coal.

My own time was fully engaged throughout the greater part of the year in directing the work of the Survey, and in editing the publications, including the Manual. Without a fully qualified Assistant permanently at head-quarters to relieve me of some of these very important and responsible duties, it is most difficult for me to undertake effectively the more congenial occupation of examining crucial questions in the field. The cumbersome arrangements for camp life, and the slowness of moving about in this way, prevent any compensating results being obtained within much less time than a full season in the field. At the same time I feel that my long experience in field work is not used for the best advantage of the Survey unless as partially applied in that way.

In February I made a short trip to the North-West Provinces, to serve on the Committee appointed for investigating into the causes of deterioration of land by *reh* in the Aligarh district. I had many years ago made some partial observations on this subject; and I have been again strongly impressed with the

extensive injury to cultivation to be apprehended from reh in connexion with canal irrigation in the excessive climate of North-Western India. My notes on the subject were submitted to the Committee, and published in its report.

I took the opportunity while in the neighbourhood to investigate two recent cases of supposed discovery of coal: one in the Siwaliks of Dehra, reported by the Railway Department, and one in the same rocks of Nāhan, to which my attention had been called by the Punjab Government. From my pretty accurate acquaintance with this ground, I was fully satisfied that the reports were fallacious; but in regard to the importance of the subject, and to the general want of confidence in independent geological judgment, I visited both localities. The result was what I expected: it would have been impossible to extract one hundred-weight of coal from all that was left of the supposed "seams." The repeated revival of these oft exploded discoveries is one of the chronic evils of the perpetual change of staff in every office throughout India.

Publications.—Two principal Memoirs, expected to be issued within the year, have been unavoidably kept back. As explained in last year's report, the letter press and plates of Mr. Wynne's report on the Salt Range, forming Vol. XIV of the Memoirs, were then ready for issue, waiting for the colour-printing of the map. This has not yet been received. Fully coloured proofs have recently been passed for press, and the issue of the report cannot now be much delayed. The postponement of Mr. Blanford's Memoir on Sind has been already explained. Mr. Foote's Memoir on the Nellore District is in hand for publication. Thus the only number of the Memoirs actually issued during the year was Part I of Vol. XV, containing Mr. Ball's report (with three maps) on the Palamow coal-fields, of which a notice has already been given. By orders of Government, the price of these volumes has been considerably reduced.

THE RECORDS for 1878 are, by way of compensation, much more full of matter than usual, extending to three times the size originally contemplated, and containing numerous outline-maps.

Of the *PALÆONTOLOGIA INDICA* two large parts were issued during the year: one by Dr. Feistmantel on the flora of the Jabalpur group, containing 14 plates, and one by Mr. Lydekker on the crania of fossil Ruminants, containing 18 plates. Two other parts by the same authors are now in the press. A revision of the somewhat confused classification of these publications has been made, for publication on the covers, from this date. The price has also been reduced.

Museum.—So far as compatible with other current work, good progress has been made in the arrangement and labelling of the collections in the new cases by Dr. Feistmantel and Mr. Lydekker in the palæontological galleries, and by Mr. Mallet in the mineral gallery. The frequent calls on Mr. Mallet for occasional assays and analyses, form a serious but unavoidable interruption to the systematic examination he is making of the mineral products of India, so far as represented in our collections.

Library.—During the past year 950 volumes, or parts of volumes, have been added to the library: 462 by purchase, and 488 by presentation or in

exchange. The new fittings in the library were completed within the year, so it will now be possible to complete the thorough arrangement of the books.

Personnel.—Mr. Hughes was absent on furlough for the whole year. Mr. Ball left on two years' furlough on the 1st of July. Mr. Lydekker was absent on privilege leave from 9th February to 8th of May; Dr. Feistmantel, from 21st of March to 20th of June; Mr. Mallet, from 2nd July to 19th of October; and Mr. King, from 27th July to 21st October.

I regret to have to record the death, on the 23rd March, of Mr. Walter Lindsay Willson, who joined the service in March 1857. He had then been for some years senior geologist on the Geological Survey of Ireland; and the training he had there received was very marked in the finished neatness of his field-maps in India.

Mr. Carl Ludolf Griesbach, F.G.S., was appointed by the Secretary of State in the room of Mr. Willson, and joined his post on the 11th November. Mr. Griesbach's acquaintance with the Karoo formation of South Africa will be of service in elucidating the supposed correspondence of those strata with the Gondwana series of India. He has accordingly been deputed to take up work for the present on these rocks in the Sone region, in continuation of Mr. Ball's survey of Palamow.

Apprentice Kishen Singh was on duty till November with Mr. Theobald, who reports favourably of his intelligence, zeal, and good conduct. Apprentice Hira Lal was on duty at head-quarters, where he performed useful service in the Museum under Mr. Mallet and Dr. Feistmantel. He was sent to the field with Mr. Griesbach in November, when Kishen Singh was recalled to take up the duties in the Museum.

H. B. MEDLICOTT,

Supdt. of the Geological Survey of India.

CALCUTTA,
January 1879. }

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1878.

AMSTERDAM.—Royal Society of Batavia.

BELFAST.—Natural History and Philosophical Society.

BERLIN.—German Geological Society.

„ Royal Prussian Academy of Sciences.

BOMBAY.—Bombay Branch Royal Asiatic Society.

BOSTON.—American Academy of Arts and Sciences.

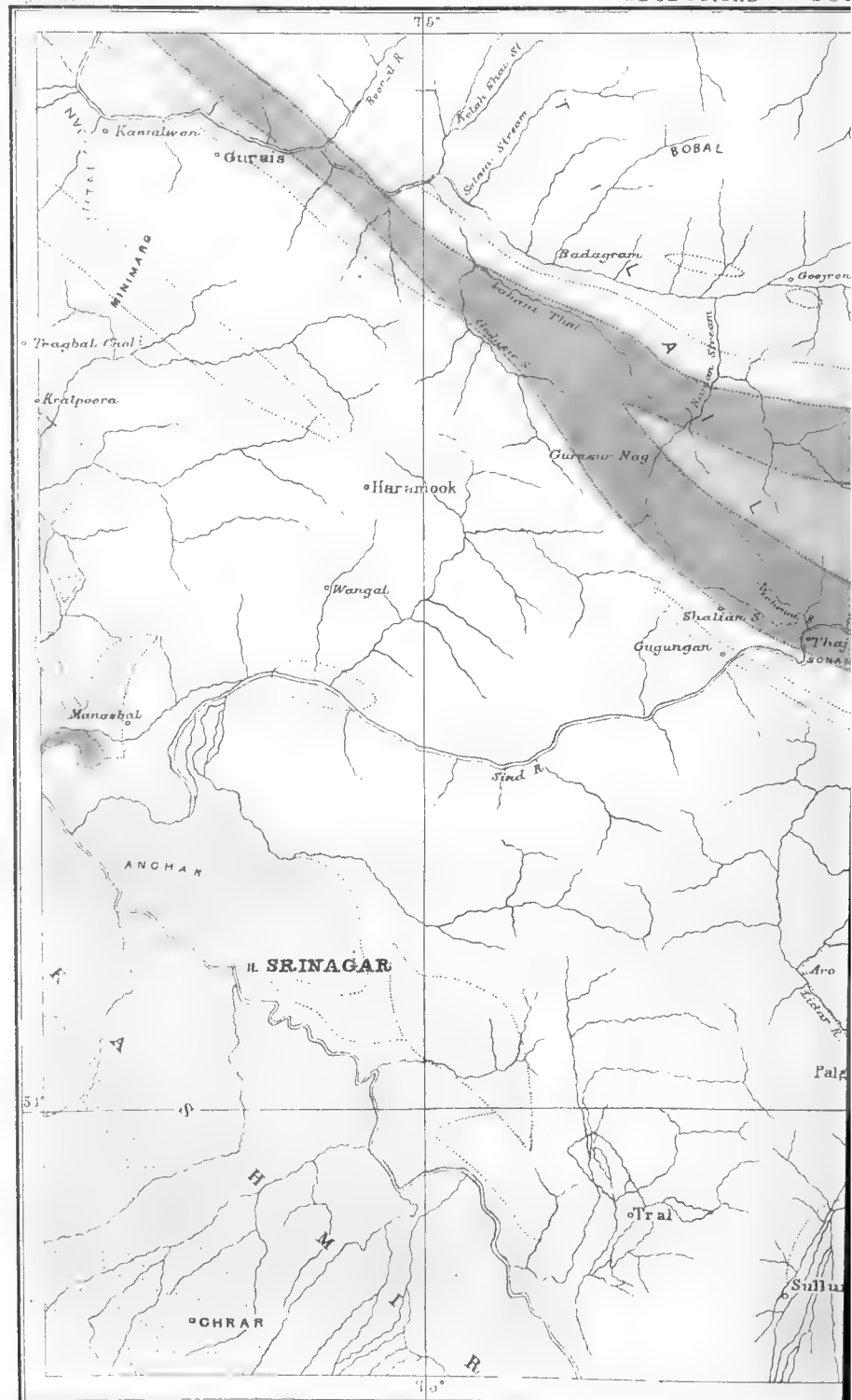
„ Boston Society of Natural History.

BRESLAU.—Silesian Society of Natural History.

BRISTOL.—Bristol Museum.

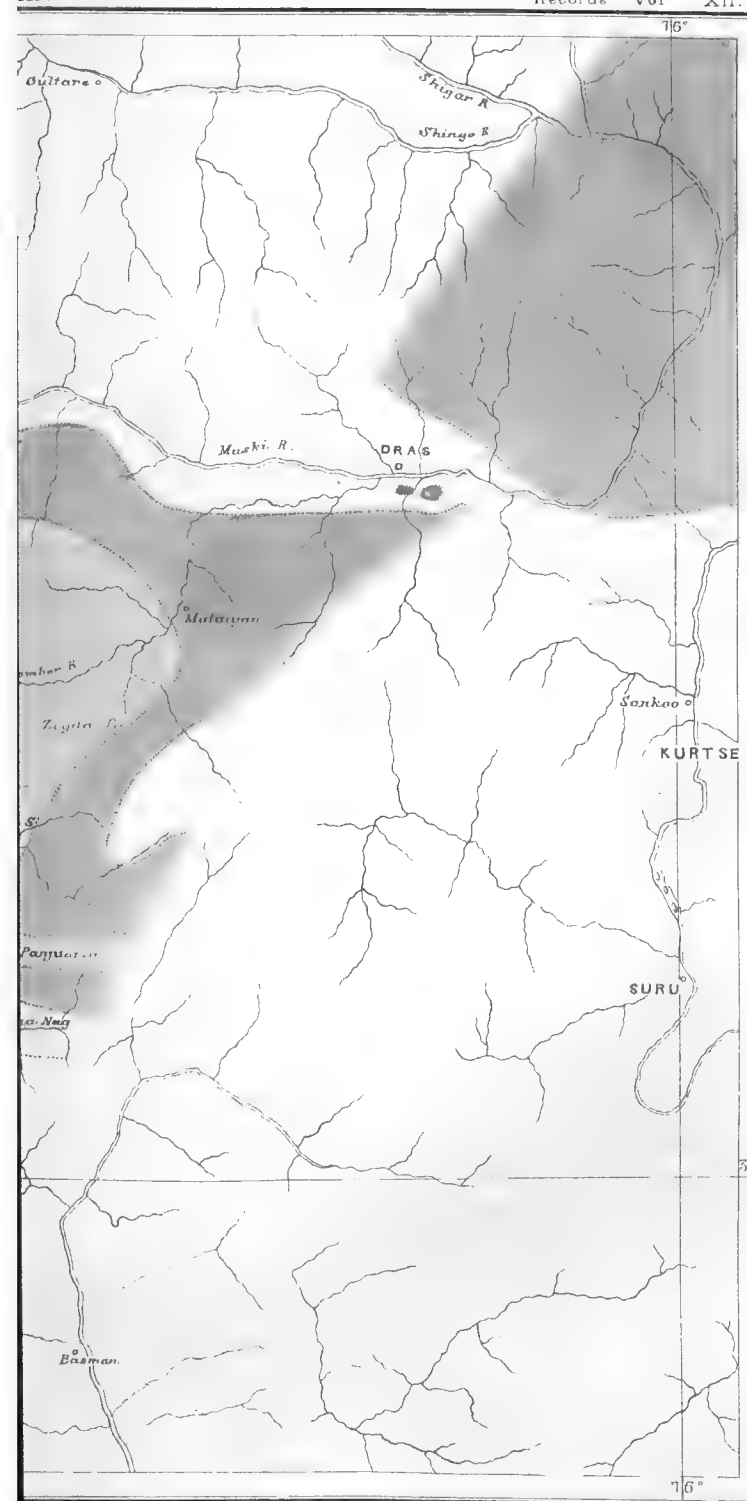
„ Naturalists' Society.

- BRUSSELS.—Geological Society of Belgium.
 „ Belgium Geographical Society.
 BUDAPEST.—National Museum.
 CALCUTTA.—Asiatic Society of Bengal.
 „ Agricultural and Horticultural Society.
 „ Meteorological Survey.
 CAMBRIDGE (MASS).—Museum of Comparative Zoology.
 CAPE TOWN.—Department of Crown Lands.
 CINCINNATI.—Zoological Society.
 COPENHAGEN.—Royal Danish Academy.
 DAVENPORT.—Academy of Natural Sciences.
 DIJON.—Academy of Sciences.
 DRESDEN.—The Isis Society.
 „ Kais. Leopold.-Carol. Deuts. Akademie.
 DUBLIN.—Royal Geological Society of Ireland.
 EDINBURGH.—Royal Society.
 GENEVA.—Physical and Natural History Society.
 GLASGOW.—Glasgow University.
 GÖTTINGEN.—The Göttingen Society.
 LAUSANNE.—Vaudois Society of Natural Science.
 LIVERPOOL.—Geological Society of Liverpool.
 „ Literary and Philosophical Society.
 LONDON.—British Museum.
 „ Geological Society of London.
 „ Linnean Society of London.
 „ Royal Geological Society of London.
 „ Royal Institution of Great Britain.
 „ Royal Society of London.
 „ Zoological Society of London.
 MADRID.—Geographical Society of Madrid.
 MELBOURNE.—Mining Department, Victoria.
 „ Royal Society of Victoria.
 „ Geological Survey of Victoria.
 MINNESOTA.—Geological Survey of Minnesota.
 „ Academy of Natural Sciences.
 MOSCOW.—Imperial Society of Naturalists.
 MÜNICH.—Royal Bavarian Academy of Sciences.
 NEW HAVEN.—Editors of the American Journal of Science.
 PARIS.—Geological Society of France.
 „ Mining Department.
 PENZANCE.—Royal Geological Society of Cornwall.
 PHILADELPHIA.—Academy of Natural Sciences.
 „ American Philosophical Society.
 „ Franklin Institute.
 PISA.—Society of Natural Science, Tuscany.



GEOLOGICAL OUTLINE OF PART O

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MUR. SCALE 8 MILES = 1 INCH.

PLYMOUTH.—Devonshire Association.

ROME.—Geological Commission of Italy.

„ Royal Academy.

ROORKEE.—Thomason College of Civil Engineering.

SALEM, MASS.—American Association for the Advancement of Science.

„ Essex Institute.

STOCKHOLM.—Royal Academy of Science.

ST. PETERSBURG.—Imperial Academy of Sciences.

SYDNEY.—Royal Society of New South Wales.

TASMANIA.—Royal Society.

TURIN.—Royal Academy of Sciences.

VIENNA.—Imperial Academy of Sciences.

„ Imperial Geological Institute.

WASHINGTON.—Department of Agriculture, U. S. A.

„ Smithsonian Institute.

„ U. S. Geological Exploration of the 40th Parallel.

„ U. S. Geological and Geographical Survey.

WELLINGTON.—Geological Survey of New Zealand.

„ New Zealand Institute.

YOKOHAMA.—German Naturalists' Society.

YORK.—Yorkshire Philosophical Society.

Governments of Madras, Bengal, and the Punjab; Chief Commissioners of Central Provinces and Mysore; Superintendents of Great Trigonometrical and Marine Surveys; Foreign, Home, and Revenue, Agriculture and Commerce Departments.

GEOLOGY OF KASHMÍR (*3rd notice*), by R. LYDEKKER, B.A., *Geological Survey of India.*

With a Map.

INTRODUCTION.

Partly owing to the famine-stricken condition of the country, and partly owing to personal disabilities, my geological work during the past summer in the Kashmír Himalaya has been of but very limited extent, and only a comparatively small area of country has in consequence been surveyed. The work which I have accomplished is noticed in the present paper which treats chiefly of the geology of the Tilail and Drás districts, and also of a few places in the valley of Kashmír which had not been previously surveyed. This paper must be read in conjunction with my two previous papers on Himalayan geology, entitled "Geology of the Pír Panjál," and "Geology of Kashmír, Kishtwár, and Pangi."¹ I shall frequently refer to the latter as "my last paper."

¹ Rec. Geol. Surv. India, Vol. IX, p. 155, XI, p. 30.

I.—VALLEY OF THE JHELAM AND KASHMÍR.

I have first to correct the map published in the "*Geology of the Pír Panjál*" in a very important point. In that map the beds at the Mozaffarábád bend of the Jhelam, north of the Mari (Murree) group, are classified as belonging to the Subáthu group. These beds consist of limestones mingled with a few slaty shales, and very strongly resemble the rocks of the latter group. At my first visit I found a few nummulites near the junction of the red clays and limestones, and I thought that they must have been derived from the latter. Last spring, however, I again crossed the river at Mozaffarábád, and after making a very careful examination of the limestone group, I came to the conclusion that this did not contain nummulites, but that those which I found on my previous visit must have been derived from the red clay series.

The limestones and slates of Mozaffarábád agree very closely in general mineralogical characters with the Uri limestones described in my paper on the Pír Panjál, and I have therefore come to the conclusion that the two must be referred to the same horizon. It is not possible, however, to trace the two continuously together, as to the south-east of Mozaffarábád the slates of the Káj-Nág come into contact with the red rocks of the Mari group.

Slates similar in character to those of the Káj-Nág range, associated with newer rocks, occur in the Hazára district to the south of Mozaffarábád, which are now in course of examination by Mr. Wynne. It seems therefore probable that the limestones of Uri and the slates of the Káj-Nág sweep round the angle of the Mari rocks at Mozaffarábád, and are continuous with similar rocks forming the ranges of the Hazára district, which have a north-easterly in place of the normal north-westerly Himalayan strike.

In the above referred to map other Subáthu rocks are represented to the west of Dewal; these are on the strike of the Mozaffarábád limestones, and it is not improbable that they also belong to the same horizon. It must, however, be borne in mind, that further south to the west of Pindi on the same strike, distinctly nummulitic limestones occur, and as there is great confusion of the rocks in many parts of this line, the position of those to the west of Dewal must for the present remain unsettled.

In my last map¹ the rocks on the left bank of the lower part of the Sind valley were left uncolored; an examination of these rocks shows that they consist entirely of the slates and sandstones of the Panjál series, having a north-easterly dip at the Dal Lake. The rocks up the Trál valley, between Srinagar and the Lidar valley, were similarly left uncolored in the same map. These rocks I now find consist entirely of slates and sandstones, mingled here and there with the Pír Panjál amygdaloids; they must doubtless all be referred to the Panjál series. These same rocks I have traced northwards to the section which I took last year between the Lidar and Sind valleys, and it is therefore apparent that the whole of the rocks

¹ *Geology of Kashmír, Kishtwár, and Pangi.*

north of the ellipse of carboniferous limestone which occurs near Srinagar must be referred to the Panjál series.

On the opposite side of the valley of Kashmír, at Gúlmarg, I have carried a section up to the central core of gneiss, which here occupies the highest point of the range, and is continuous with the gneiss shewn in my last map to the south-east of the Jhelam valley. The gneiss above Gúlmarg has the same relation to the slates and sandstones as has the corresponding gneiss of the Pír Panjál pass to the same series. This relation and the inferences drawn from it will be found in my last paper.

II.—SIND AND TILAIL VALLEYS.

The greater part of the Sind valley section has already been described in my last paper. During the past summer, however, I had occasion to re-traverse this line, and some further remarks on the section which occurred to me during this second visit have been added in the present paper. My great object in this journey was to trace the limestone series of Sonamarg and Amrnáth (Ambarnáth) to the north-west, and I shall describe below the sections as they were met with on my route: it may be well in the first place to mention the route I took.

Starting from the valley of Kashmír, I travelled by the Ladák road as far as the town of Drás; from thence I turned off to the westward, crossing the pass into the Tilail valley; I then followed the Kishenganga¹ river as far as Gurais, making several detours to the northward. From Gurais I returned to the village of Bodagrám in Tilail, and from thence struck across the hills in a south-easterly direction *viâ* the Lahani and Gadasir valleys to Sonamarg in the Sind valley. A separate trip from Kashmír to Gurais along the Astor road enabled me to connect the north-westerly extremity of the Tilail section with the previously known rocks of the valley of Kashmír.

At page 47 of my last paper I referred to a mass of gneiss mingled with a few bands of limestone which occurs in the lower part of the Sind valley, south of the village of Wangat. I then suggested the possibility of this gneiss being newer than the slate series. A further examination of these rocks has, however, led me to come to the conclusion that the gneiss series really underlies the slate and amygdaloidal series, and that the former must consequently correspond in position with the gneiss of the Pír Panjál. The peculiarity of the Sind valley gneiss is, that it contains some beds of unaltered blue limestone and others of white crystallised limestone; the occurrence of this limestone with the gneiss cannot, however, of itself, I think, be regarded as of any importance as regards the age of the rock. Very similar limestones occur in the gneiss of the Bhútna river in Pangi, which were noticed in my last paper.

Above this mass of gneiss I have no additional remarks to make on the Sind valley section, until we come to the great limestone series of Sonamarg. In rela-

¹ The name of the Kishenganga river does not appear on the map. It should be applied to the river which rises in Tilail above Gújrond (Goojrond), and from thence flows to Gurais.

tion to this series I must observe that in my last published map, the boundary lines of this formation on the Drás side of the Zoji pass were taken from unpublished notes left by the late Dr. Stoliczka; a traverse of this route by myself has shown me that some error had crept into the map as to the position of the north-eastern boundary of the Zoji-la slates which was put much too near the pass; this error was most probably due to some misinterpretation of the notes left by Dr. Stoliczka.

As I had not proceeded beyond Sonamarg when I wrote my last paper, I shall take up the section from that place; the preceding descriptions of this section will be found at page 46 of my last paper of which this must be taken as the sequel.

An anticlinal axis traverses the Sonamarg limestone series in a north-westerly and south-easterly direction near the village of Thájwaz; this axis, as is noticed by Dr. Stoliczka,¹ is continued from thence along the course of the Sind river as far as the halting place of Báltal, at which point it bends round abruptly to the southward. As we ascend the Sind valley from Sonamarg, we find higher and higher beds forming the exposed base of the anticlinal, till at Báltal the rocks consist in great part of white dolomitic limestones like those of Amrnáth cave, described in my last paper. A great portion of the lower white dolomitic rocks of the latter place are replaced in the Sind valley by blue banded limestones intermingled with slates.

Immediately above Báltal, the limestones, with a north-easterly dip, are succeeded by the slates of the Zoji-la, with the same dip: these slates soon become nearly vertical; they are often columnar or bacillar in structure, and contain bands of limestone; immediately north of the Zoji pass, we find a band of this intercalated limestone some fifty feet in thickness; this limestone is underlaid by slates, and again appears further down across an anticlinal flexure in the same slates. Alternations of slates, micaceous sandstones, and quartzites, with occasional bands of limestone, continue along the Drás road, till we get within half a mile of Mataian: these rocks in many places are greatly disturbed by contortion.

Above Mataian we come upon blue limestones underlying the slates; the former are again underlaid by white dolomitic limestones like those of Amrnáth; these limestones indeed bend round to the east of the Gúmbar (Goomber) stream to meet those of the latter place.

We have already seen that the triassic limestones and dolomites of Sonamarg, according to my view, underlie the slates at Báltal and Mataian, in which respect the sequence here exactly agrees with that which I have shown in my last paper² to occur more to the eastward at Panjtarni. Further, we have seen that a distinct anticlinal flexure traverses the limestone series at Báltal, which disproves the

¹ Scientific results of Yarkand Mission—Geology, p. 12.

² Page 45.

alleged superposition of the triassic limestones on the Zoji-la slates.¹ Across the Zoji-la pass, however, owing to the great amount of contortion which the rocks have undergone, the sequence cannot be clearly traced, though I incline to think that the whole of the rocks between Báltal and Mataian are newer than the triassic limestone series. Beyond the Zoji pass, however, there occur on the road a few blocks of a gneissoid rock coming from the eastward, which may show that certain older rocks are thrown up by faults within the presumed triassic area. I have no positive proof, however, that such is the case, and I do not therefore desire to lay any great stress one way or the other upon the presence of a few gneissoid rocks within this area.

At Mataian there is a small fold in the white dolomitic limestones, and below this the same rocks continue with a southerly or south-westerly dip to the great bend in the Gúmbar river. At this bend the triassic series is faulted against another great rock series, which has a northerly dip; for a short distance below this bend the river runs along a faulted anticlinal axis, while further down the dolomitic series is continued to the eastward a little to the south of the river: the dolomitic rocks have in this direction been traced a little to the eastward of Drás. The rocks² to the north of this fault have a general blackish color when seen from a short distance, which contrasts most strongly with the white colored dolomites to the south. These slaty rocks to the north and east of Drás are abruptly cut off by a great mass of crystalline rocks. These crystalline rocks are mentioned by Dr. Stoliczka in his "Geological Observations in Western Tibet" under the name of syenite, and are traced down the Suru river. In the latter area, according to Dr. Stoliczka, this rock contains large crystals of hornblende and diallage, with occasional nests of epidote and serpentine, together with grey quartz, and albite, and occasionally orthoclase. A rock of this composition is of course rightly named syenite: at Drás, however, the composition of the rock appears to have changed; in hand specimens, which I collected, its constituents are quartz, brown uniaxial mica, and one or two kinds of felspar, and apparently no hornblende. The Drás rock, therefore, seems to be a true granite, and the same composition prevails in these rocks as we proceed to the east.

A portion of the slaty rocks of Drás was considered by Dr. Stoliczka (sup. cit., p. 349) to be of silurian age, while another portion was considered to be of

¹ There appears to be some confusion in Dr. Stoliczka's account of this section. At page 349 of his "Geological Observations in Western Tibet," he observes, "these rocks (Zoji-la slates) are overlaid—neglecting interruptions—by limestones and carbonaceous slates," making no mention of the anticlinal in the limestones. At page 12 of the *Geology of the Yarkand Mission*, he observes that the limestones near Sonamarg have 'a northerly dip on the right bank of the valley,' and immediately afterwards he says, that some four miles to the east on the same strike these limestones which dip towards the slates are *underlaid* by the slates, which is, so far, contradictory. In my last paper on Kashmir geology (p. 45), I assumed from Dr. Stoliczka's first account that there must be inversion. Now that I have visited the spot, however, it appears to be a regular sequence, though somewhat contorted, but a sequence which agrees exactly with the less disturbed one at Panjtarni.

² Mem. Geol. Surv. India, Vol. V, p. 347.

carboniferous age; no fossils were, however, discovered. We shall subsequently see that these Drás slates are the equivalents of the Pír Panjál rocks of Kashmír, and therefore appear to be the equivalents mainly of the silurians, though there is no reason why some of their higher beds should not be carboniferous. The same rocks may be traced in a south-easterly direction to Kurtse, where they overlie the gneiss of Suru.

Near the town of Drás itself the slate series has generally a very massive character, showing at a short distance but very indistinct signs of stratification; the rocks consist mainly of brown or purple sandstones, and black, brown, green, and brick-red slates and shales. To the westward of Drás, the same rock-series is continued up the Muski stream, with a generally northerly dip; a little to the south of the same stream, we may trace the bold line of cliffs of the triassic dolomites, which have a generally westerly trend, and the same southerly dip which we observed at Drás. Westward of Drás many of the rocks in the slate series consist of light colored ribband-jasper, and there are also numerous beds of conglomerate intercalated with the slates. The pebbles in this conglomerate are sometimes water-worn and sometimes angular, and do not generally exceed four inches in their longest diameter; they consist of quartzites, grits, and slates, some of the two latter of which are very similar in character to the main rock. The occurrence of pebbles in these rocks similar to the matrix, may perhaps be explained in the manner in which Sir Charles Lyell explains a similar feature in the Stonesfield slate of England;¹ he there suggests that the pebbles in the conglomerate, which resemble the main rock, may be portions of the same deposit which have been broken up in shallows and re-deposited. The rocks may, however, have been altered before the formation of this conglomerate.

About twelve miles above Drás on the Muski river, a few thin bands of limestone occur in the slate series; nearer the pass, at the head of the river, black slates and conglomerates are the prevalent rocks.

As we approach the pass separating the Drás and Kishenganga valleys, blue limestones begin gradually to appear at the top of the slate series (which has a southerly dip), till finally at the pass itself these blue limestones form the greater portion of the higher part of the series; still further to the south these blue limestones are overlaid conformably by the buff dolomitic limestones continuous with those south of Drás, in which Dr. Stoliczka found triassic fossils.

We therefore find that at the head of the Muski stream a very different condition obtains to what we found at Drás; at the latter place we found a fault separating the Drás slates from the triassic dolomites, while in the former place the two series are connected by an intervening series of blue limestones, the whole being apparently conformable. The inference from this is *firstly*, that the fault which occurred at Drás has here died out, *secondly*, that the intermediate blue limestones belong approximately to the carboniferous series, and *thirdly*, that the Drás slates belong approximately to the silurian series. The carboni-

¹ Student's Elements of Geology, p. 323.

ferous limestone I estimate here at 3,000 feet in thickness, and the triassic as from 4,000 to 6,000 feet.

Down the Tilail valley, nearly to the Búrzil (Boorzil) river, the blue carboniferous limestone continues a little to the south of the Kishenganga, overlying the slates, and itself overlaid by the dolomitic limestones of the trias; these latter, more especially in the pass between Drás and Tilail, from their uniform and homogeneous character, weather into grand tower-like cliffs and crags, showing very little signs of stratification. The banded carboniferous limestones, on the other hand, which generally contain intercalated beds of slate, weather into bands parallel to the stratification.

On the right bank of the Kishenganga river in Tilail, there is an anticlinal axis a little north of the limestone series, and again, beyond this, a synclinal axis; in this synclinal axis there occurs a broken line of presumably carboniferous limestone. To the north of this synclinal I have traced the slate series, which has a generally southerly dip, to the summit of the Tilail watershed; black slates here form the higher portions of the series, while sandstones and grits are more common lower down. Lower down the Kishenganga valley, during a shooting tour made in 1874, I also traced the same slate series to the watershed of the Kelah Shai and Satani streams; it is therefore apparent that this silurian slate series extends to the northern watershed of the Muski and Kishenganga valleys, from Drás to the Búrzil river. I may mention that in the fine-grained black slates which occur high up in the Kelah Shai valley, I found in 1874 obscure organic impressions which I thought might possibly belong to *Graptolites*. I have unfortunately since lost these specimens, so that I cannot confirm this opinion.

Returning to the middle of the Tilail valley, near the village of Bodagrám, we find that green amygdaloids like those of the Pír Panjál are of common occurrence in the slate series, from which I think we may safely conclude that the Drás and Panjál series are of the same age. This coincides with the inference drawn as to the age of the Drás slates from their relations to the triassic dolomites.

We have now to take an oblique cross-section through the great limestone series, from the village of Bodagrám in Tilail to Sonamarg in the Sind valley. In crossing the ridge on the left bank of the Kishenganga, separating that river from the Lahani stream, we first pass over a continuously ascending series of light blue carboniferous limestones with a southerly dip; as we descend on the opposite side of the ridge into the Lahani valley, we find these blue limestones succeeded conformably by bands of white dolomitic limestones, pure blue limestones, green slates, and a peculiar white slaty limestone. On the Lahani stream there occurs a thick band of brownish slates; these and other slates intermingled with a few bands of limestone, with the same southerly dip, extend halfway up the ridge separating the Lahani from the Gadasir stream; here we find the slates overlaid by white, buff, and blue dolomites and limestones. Crossing the ridge into the Gadasir valley, we come upon a synclinal axis, and as we descend we cross the same beds in a reversed direction. The lowest of these northerly dipping beds,

however, exposed in the Gadasir stream are the dolomites and limestones, and not the underlying slates seen in the Lahani stream.

It will, I think, be evident from this section that the last-mentioned dolomites and limestones must be the representatives of the pure white triassic dolomites which occur further to the east; it is, however, not quite clear whether the brown slates in the Lahani valley belong to the carboniferous or to the triassic series; as, however, dolomitic limestones and a whitish calcareous slate occur below these brown slates, and as the thickness of the carboniferous limestones, north of the Lahani stream, is about equal to that which occurs more to the eastward, I have thought it probable that the slates near the Lahani stream and the overlying dolomites and limestones all belong to the triassic series, and I have accordingly so colored them in the map. The slates which occur in the middle of the limestones not improbably indicate that we have here a littoral deposit in a subsiding area, and that as subsidence went on more rapidly, limestones were again thrown down over the slates.

As the triassic series has not in this place the homogeneous structure which is so characteristic of it, further to the eastward, the general appearance of the rocks is very different; they do not weather out into the craggy peaks like those of Amrnáth and Drás, but into parallel hollows and ridges, accordingly as the harder or softer beds are more prevalent: in this respect resembling the triassic series at Sonamarg, as described in my last paper.

Reverting now to our section, we find on the left bank of the Gadasir stream, tall cliffs composed of the amygdaloidal rocks of the Pír Panjál series, which I have traced to the south-east into similar rocks forming Shalian ridge, which were described in my last paper; to the north-west these rocks continue on towards Gurais, where I shall have again to refer to them. The boundary between the triassic and silurian rocks continues up the Gadasir stream, and by the two small lakes called Kishan-Sar at the head of the Raman stream, and thence again down the Nichinai stream, till it reaches Thájwaz, where it was described in my last paper. White dolomitic limestones are most prevalent at Kishan-Sar, but towards Thájwaz blue limestones with slates are more prevalent; corals and crinoids are extremely abundant in the dolomitic limestones near the head of the Gadasir stream, the rocks at this place having evidently once formed part of an old coral reef.

For some way down the Gadasir stream, the junction between the slate and limestone series is a faulted one; this is rendered evident by the fact that the higher dolomitic limestones in the Gadasir valley rest against the nearly vertical silurians, while at Thájwaz the limestones in which Dr. Stoliczka found a triassic Ammonite dip towards the older silurians. Lower down the Gadasir stream, however, as we shall see at Gurais, the fault dies out, and there is an apparently uninterrupted succession from the presumably silurian slates to the triassic dolomites.

As accessory evidence in regard to the Gadasir-Nichinai fault, it may be observed that along the whole of this junction, a line of springs of extremely pure

water bursts forth. These springs, which have a temperature of about 50° F., in great part supply the two small lakes called Kishan-Sar above referred to. These lakes are situated at an elevation of a little short of 13,000 feet above the sea; and my guide from Tilail told me that they never freeze, even in winter, which is owing to their being supplied by these springs whose temperature I presume to be nearly constant. I at the same time paid a visit to another small lake called Gurasar-Nág, within the silurian area, and consequently off the line of springs; in this lake, which is situated at about the same elevation as the others, I found, at the latter part of August, huge masses of snow floating about in the water, and the temperature of the water at freezing point, while the temperature of the water of Kishan-Sar I estimated at over 40° F., though glaciers drain into it.

From these facts there can be little doubt but that the above referred to line of springs is of very deep-seated origin, which is strongly in favor of their being forced up from the depths of a fault between the limestone and slate series.

I may mention in passing that the mountain lakes referred to above are situated in hollows, the mouths of which are dammed by the moraines of old glaciers, of the former existence of which there are here abundant evidences.

Returning once more to our section, it firstly remains to mention that the band of carboniferous cherty limestone, described in my former paper as occurring at the top of the slate series at Gaggangan (Gungungan) in the Sind valley, and thence continued to the north-west, dies out across the watershed of the Sind valley, and the amygdaloidal silurians of the Shalian ridge consequently come into immediate contact with the slates of the Sind valley, though I am unable to say whether or no the fault is continued.

It now remains to consider the limestone series near Gurais, but before doing so it will be simpler to carry a section from the valley of Kashmir to the latter place, in order that we may the more thoroughly understand the sequence. Starting from Kralpúr (Kralpoora) on the Gurais and Astor road, we find near that village, that the rocks consist chiefly of amygdaloids and slates, an anticlinal axis running through them close to the village. Between Kralpúr and the halting place of Trágbal, the rocks have a general flat northerly dip; the amygdaloidal rocks become relatively fewer as we ascend, and are replaced by green and black or brown slates and sandstones; above Trágbal the rocks consist almost entirely of black slates which preserve the same north-easterly dip till we approach a synclinal axis, near the pass, which is again shortly followed by an anticlinal axis. Descending from the pass towards Kanzalwan, after a few miles we come upon a band of micaceous and gneissoid rocks, with a northerly dip, apparently overlying the black slates. It is, however, quite possible that a fault may occur at the base of these gneissoid rocks, and they may consequently be at the base of the slates. There is, I think, from its mineral character, little doubt but that this gneiss is the same as that of the Pír Panjál, which I have considered in my former papers to be at the base of the slates. Irrespective of any other considerations, it would be extremely improbable that a band of gneiss, in localities so far apart

as this and the Pír Panjál, always occurred in the middle of the slates, whereas it would be extremely probable that it should occur always at their base.

Beyond this gneiss, still descending the stream, we find black slates conformably overlying the crystalline band, while towards Kanzalwan a few of the Pír Panjál amygdaloids occur intermingled with the slates, showing that we are still in the silurian series. Leaving Kanzalwan, the rocks along the Kishenganga river consist of the peculiar bluish-green slaty sandstones which were noticed in my last paper as occurring below the carboniferous limestones at Chandanwari, in the Lidar valley. As we approach Gurais, these rocks are overlaid by blue limestones with the same north-easterly dip; the blue limestones are followed by blue and white limestones in bands, the whole being capped by white dolomites like those of Amrnáth. In 1874, during the shooting-trip previously mentioned, I found at the base of these limestones a larger species of *Clymenia*,—a genus characteristic of the upper devonian.

From the conformable position of this limestone series on the top of the slates, and from the occurrence of the above-mentioned fossil, it seems probable that we have here a regular ascending rock series, from the silurian to the trias inclusive; I cannot, however, put in any distinct devonian group, or draw any arbitrary boundary between the carboniferous and the trias. I have accordingly merely coloured in the former rocks as forming a band corresponding to their average width in other localities, which I have made to die out towards the south-east, where, as we have seen, there is a faulted junction between the slate and the limestone series, and where the carboniferous or lower limestones are probably wanting.

Near Gurais bands of a conglomerate occur in the slate series similar to the conglomerate of the Pír Panjál range; this conglomerate contains pebbles of granite or syenite, similar to that of Drás, which rock must, consequently, be older than the slates, and must have existed in its present condition at the time of the deposition of the latter. Pebbles of the same crystalline rocks occur in the bed of the Búrzil river, which seems to indicate that these rocks are continued to the north of the Tilail watershed into the higher valley of the Búrzil. It also seems probable, that these same granitoid rocks have a great extension to the east, forming the rocks on the right bank of the upper Indus at Lè, where they are variously referred to by Dr. Stoliczka as "granitic and syenitic rocks"¹ and "syenitic gneiss"². In the latter districts, they were considered by Dr. Stoliczka as forming, in all probability, part of the silurian series; there being apparently in the Lè district no break between these rocks and overlying shales supposed to be of carboniferous age.

There is, however, quite a possibility of there being a hidden unconformity in the Lè district, which would correspond to the unconformity at Drás, shown by the crystalline pebbles in the slates, and I would suggest that it may possibly turn

¹ Geological Observations in Western Tibet, p. 343.

² "Scientific Results of Yarkand Mission"—Geology, p. 15.

out that some of these Drás and Lè crystallines are the representatives of some of the crystallines in Suru and Lahúl, where there is a probability of rocks of two ages being intermingled.¹

The unusually wide area over which the Pír Panjál conglomerate (if that of Pangí be the same) extends in the slate series, is a very remarkable circumstance, and must clearly be due to some very wide-spread cause. In the Pangí district I have elsewhere stated that it seemed to me to be extremely probable that ice action has been connected with its production, and considering its wide distribution in Kashmír, I am beginning to think whether we must not have recourse to some similar transporting power there, though I have at present no positive proofs to bring forward. The occurrence of gneiss (or syenite?) pebbles in the conglomerate of the Pír Panjál, which, we have seen, cannot belong to the gneiss of that district, may be considered as tending towards the hypothesis of ice-transport.

It now remains to say a few words regarding the area between the Sind valley and the Trágbal and Gurais road. It will be found from my last paper that with the exception of the gneiss in the Sind valley, all the rocks in the valley of that river below Gaggangan belong to the silurian series; the same rocks, with the exception of a few others of carboniferous limestone, bound this area to the southward along the vale of Kashmír; similar rocks bound this area to the north-west on the Gurais road, with the exception of the band of gneiss noticed above; on the north-east the same rocks underlie the limestone series of Tilail. It is therefore evident that the area in question is occupied by rocks of the Panjál series, which strike right across it, but that the centre of this area is penetrated by a mass of gneiss running in from the north-west, which, however, does not reach into the Sind valley. On a former occasion I have found this gneiss occurring high up in the valley to the east of Kralpúr, and on the northern flanks of Haramúk (Haramook). It seems therefore evident that this band of gneiss dies out somewhere on the north-western side of Haramúk, and that the rest of the area consists of the rocks of the Pír Panjál. The area has accordingly been colored in on the map, though the boundaries of the gneiss must be only regarded as an approximation to the truth.

A general glance at the map of the north-eastern side of Kashmír, will, on the whole, show us that the geological features of the country are very similar to those of the Pír Panjál and valley of Kashmír, as treated of in my last paper. We there found that the centre of the Panjál range seemed to be an anticlinal axis, flanked on the outer side by limestones considered to be of carboniferous age, and followed on the inner side by the synclinal axis of the vale of Kashmír containing undoubtedly carboniferous rocks.

Similarly, on the Gurais road, we find an anticlinal axis showing gneiss, followed by the synclinal of the Gurais valley, containing carboniferous and triassic strata again underlaid by silurians to the north-east.

¹ Rec. Geol. Surv. India, Vol. XI, p. 60.

To the south-east of Haramúk, this northern anticlinal is not so well marked, as no gneiss is shown in the section; while still further to the south-east, as at Palgám in the Lidar valley, the anticlinal has quite died out, and is replaced by a local synclinal, in which there rests an outlier of carboniferous strata.

The synclinal in the silurians at Gurais, containing carboniferous and triassic strata, is a well marked feature, extending from the former place to Panjtarni and Drás towards the south-east. In many places, however, it will be observed that the original relations of this synclinal have been disturbed by faulting, but not to such an extent as to obscure the general features of the system. To the north of this great synclinal ellipse, we have another slight synclinal containing carboniferous strata in the midst of silurian rocks.

It will have been observed in the course of the preceding sections, that the slates of the Zoji-la, lying in a synclinal ellipse of the triassic limestones, are not represented in the section taken from Tilail to Sonamarg; the synclinal being contracted at this point. It is therefore apparent that these slates must die out gradually between the Zoji-la and that point; this has accordingly been so represented in the map, though the north-western termination of these Zoji-la slates is only approximately represented.

In concluding this sketch, I wish to add a few words regarding the probable age of the strata overlying the silurian series, in the Tilail and Drás districts, and their relations to the great limestone series of the valley of Kashmír. I would premise that fossils are of extremely rare occurrence in this series, and that therefore no precise distinctions as to the age of the different beds can be drawn, but only the general homotaxis of the series can be roughly indicated. I have already observed in my last paper, that in the fossiliferous strata of the more eastern Himalaya, the late Dr. Stoliczka found that no distinct devonian or permian periods could be determined from the fossil evidence, but that strata containing a fauna with a distinct silurian *facies* were immediately followed by other strata containing a fauna with a carboniferous *facies*, and the latter again by a triassic fauna. The absence of a distinct devonian and permian period cannot here be explained, on the supposition that during these periods the area was dry land, since (unless there be concealed breaks of which we have no knowledge) there seems to be an uninterrupted succession of strata; and we are therefore driven to conclude that the strata classed by Dr. Stoliczka as silurian, carboniferous, and triassic, must be the representatives of the whole of the European series from the silurian to the triassic inclusive; and that the same probably holds good in the Kashmír area.

On these grounds it would not appear surprising, if we were to find a commingling of the fossils of all these different periods, to a certain limited extent; and such appears to be certainly sometimes the case in India, since Dr. Waagen¹ has described the occurrence of Ammonites associated with Goniatites in the carboniferous strata of the Salt Range, clearly showing a blending of the carboniferous and triassic faunas.

¹ Mem. Geol. Surv. India, Vol. IX, pt. II.

Returning now to our Kashmír limestones, we find that in the valley of Kashmír at Eishmakám and near the Marbal pass, as well as in a few other places, distinctly carboniferous fossils have been found, generally low down in the series; a few similar fossils have also been found at the base of the limestone series of the north of Kashmír, near Shísha-Nág, which seems to correlate the bases of the two local series. Further to the westward at Thájwaz, a triassic Ammonite was found by Dr. Stoliczka somewhat low down in the limestone series, but how low down I am unable to say, because the junction between the limestone and slate series is here a faulted one. A little higher up in the same series I have myself found corals and crinoids.

At the top of the Gadasir stream, I found what seems certainly to be a *Chatetes* in considerable quantity; and at Sonamarg I found one large mass of a *Cyathophyllum* or some closely allied genus. Now, the genus *Chatetes* has been hitherto known in the Himalaya from the Muth series¹ only, which is supposed to be the representative of the European silurian, while we now have it on a line of beds which have yielded a triassic Ammonite. In Europe the genus attained its maximum in the carboniferous rocks, but also ranged both above and below that formation.

Cyathophyllum also, according to Dr. Stoliczka, has hitherto been found only in the Muth series in the Himalaya; in Europe this genus ranges from the silurian to the trias.

As far as these two genera go, therefore, it seems that no evidence of the age of the rocks in which they occur can be obtained. The discovery of these in the triassic series of India shows that they had a wide range in time here as in Europe.

Again, near Drás, in the dolomitic series, which corresponds to some parts of the limestone series at Thájwaz, very characteristic upper triassic fossils were found by Dr. Stoliczka.²

Turning now to the same great limestone series at Gurais, we find that here we have an apparently continuous series from the Panjál slates through the limestones; and that quite at the base of these limestones a species of the genus *Clymenia* was found which is characteristic of the upper devonian of Europe.

Taking, therefore, the whole of this evidence, it is quite clear that the base of the limestone series of Kashmír is of carboniferous, and from the evidence of the *Clymenia* perhaps partly of upper devonian age. The higher dolomitic beds, on the other hand, are clearly of upper triassic age. The only question is where to draw the boundary between the two periods.

Now, at Thájwaz, where the Ammonite was found, and where the junction is faulted, the strata have been colored in the map as of triassic age; it must, however, be said that an anticlinal occurs here, and that no very distinct lithological comparisons are here possible. Moreover, as the whole series is here in sequence,

¹ Stol.: Mem. Geol. Surv. India, Vol. V, part iii, p. 143.

² Mem. Geol. Surv. India, Vol. V, p. 349.

and as we have already seen that Ammonites have been found elsewhere in India in strata containing carboniferous fossils, it is not improbable, nay rather it is very probable, that there may here be a mingling of fossils of different periods; and that consequently no hard-and-fast boundaries can be drawn corresponding to the limits of European formations; though at the same time it should be observed that it may hereafter be quite possible to distinguish independent Indian life-zones in these strata, should abundant fossils ever be discovered in them.

In the map wherever there is a regular sequence of strata from the Panjál slates to the upper triassic dolomites of Drás and Amrnáth, the limestones underlying the latter have been classed as carboniferous. Along the faulted line of Thájwaz the whole series has been referred to the trias from the evidence of the Ammonite, which, as above said, may be doubtful; and there may therefore be a few carboniferous beds at the base of the anticlinal, while at the same time some of the higher slates may be of carboniferous age.

We may also observe that since the limestones of the valley of Kashmír itself, which contain numerous carboniferous fossils at their base, are in many places thicker than the carboniferous band in the limestone series of the north of Kashmír, it is more than probable that some portions of the former are the representatives of the triassic series. At Mánasbal¹ this has already been proved to be the case, from the identity in mineral character of the white dolomites at the top of the series in that place with the similar rocks of Drás and Amrnáth. In the south-eastern extremity of the valley of Kashmír, the whole of the limestone series has the same mineralogical composition throughout, and the higher beds have hitherto yielded no fossils. We have therefore no direct evidence to connect the upper beds there with the trias of Drás, and they must therefore remain on the map as of carboniferous age, until evidence can be produced to the contrary.

Finally, we must come to the conclusion that the Kashmír limestone series forms an unbroken sequence of strata, which must be the equivalents of all the European strata from the upper devonian to the upper triassic inclusive; but as, with one exception, no devonian or permian fossils have been discovered, the strata have been colored on the map as carboniferous and triassic only.

From the distribution of the limestone series in Kashmír, it seems pretty evident that these strata were once connected and extended over the whole area, and have been brought into their present form by disturbance and denudation.

The strata overlying the triassic dolomites of the Zoji-la being sandy and clayey in composition, were probably deposited in a shallower sea than that in which the older limestones were laid down; and since no newer strata are known in this area, it is possible that the bottom of the sea was being upheaved at the time of the deposition of these slates, and that the area has not subsequently been submerged.

¹ Rec. Geol. Surv. India, Vol. XI, p. 47.

The local occurrence of clayey and sandy rocks in the limestone series on the horizon of pure limestones may also suggest that the sea in which these limestones were laid down was in places shallow, and near to land; the presence of coral reefs also attests either the presence of land, of a shallow sea, or of a sea filled with atolls. Where the ancient land surfaces were, we have at present no mean of indicating.

III.—TRACES OF OLD GLACIERS IN KASHMÍR.

As there has been considerable discussion carried on in the "Records" of late concerning the supposed glaciation of parts of the Upper Punjab, I have thought it would not be out of place to state here any facts which I have observed as to evidences of former glaciation in Kashmír and the neighbouring mountains.

I will first observe that I have nowhere observed any traces of glaciation in the valley of Kashmír itself. I have already observed in my last paper,¹ that I cannot agree with Professor Leith Adams² in considering the Baramúla gravels as affording any evidence of former glaciation; and I know of no other deposits in the valley which could possibly be considered to be due to the same agency. Neither have I seen any traces of erratics, perched blocks, *roches moutonnées*, or scratched rock-surfaces within the limits of the valley. I may add that I think it almost certain that the Baramúla gravels are much older than the old glacial moraines of other parts of Kashmír, which are always entirely undisturbed by tilting.

The lowest elevation in Kashmír at which I have observed glacial phenomena is in the Sind valley near the village of Kúlan, (marked in the map issued with my last paper), at an elevation of about 7,000 feet; here I have seen very distinct glacial striation. Mr. Drew,³ moreover, mentions the occurrence of a well grooved *roche moutonnée* near the same place at an elevation of about 6,500 feet above the sea level, or 1,500 feet above the level of Srinagar. This is the lowest spot in Kashmír, where there seems to be undoubted evidence of former glacier action.

Above this elevation traces of old glaciers are extremely numerous in the Kashmír Himalaya; and I will here only notice one or two well marked instances.

At Gúlmarg, on the Pír Panjál, many of the hillocks of detrital matter stretching out into the valley seem undoubtedly from their shape to have formed part of an old glacier moraine, though I have not succeeded in obtaining any grooved rocks; the elevation of this place is somewhat short of 8,000 feet.

At Sonamarg and Thájwaz, in the upper Sind valley, there is an undulating plateau, at an elevation of about 9,000 feet, which is composed entirely of detrital matter, to a depth in places of at least 300 feet. This plateau has been admirably described at page 220 of Mr. Drew's above-quoted work on Kashmír, and is there clearly shown to have once formed an old glacier moraine. I have found glacial

¹ p. 33.

² Wanderings of a Naturalist in India, p. 171.

³ Jummoo and Kashmír Territories, p. 220.

scratches on some of the angular blocks of this moraine. The blocks in this moraine consist almost entirely of the amygdaloidal rocks of the Shalian ridge, while the moraine itself rests in a hollow of the Sonamarg limestone. At an elevation of about 2,000 feet above the Sonamarg plateau three small glaciers still nestle in sheltered ravines on the northern aspect of the Shalian ridge. Mr. Drew thinks it probable that the whole of the Sind valley nearly as far down as Kangan was formerly occupied by a glacier—a conclusion with which I agree. The hill of limestone separating the village of Sonamarg from the valley of the larger Thájwaz glacier, represented at page 219 of Mr. Drew's book, is at its lowest point some 500 feet above the level of the Sonamarg moraine, and has a peculiarly rounded appearance, which suggests the probability of this hill having been once buried beneath the ice of the old glacier.

On the Ladák side of the Zoji pass, we find at Drás, which has an elevation of some 10,000 feet, two huge embankments of detrital matter, some four or five miles in length, extending from the crystalline ridges of the north into the Drás valley, and consisting almost entirely of boulders of the crystalline rocks strewn the surface of the slate rocks of Drás. From the form of these masses of detrital matter, I think that they are certainly due to former glacial action; which opinion is strengthened by the great distance over which the boulders have travelled, and by the very slight fall of the ground on which they lie,—a fall so slight that I cannot think these huge blocks could have possibly been moved along it by the action of water alone, especially as there is no great river along the line of their course.

It now remains to consider certain granitoid blocks in the Jhelam valley below Baramúla which Colonel Godwin-Austen¹ suggests may have been brought into their present position by the aid of ice-action. In discussing the question of the glacial or non-glacial origin of the deposits in which these blocks occur, it will be necessary to go somewhat into the history of the Jhelam valley.

On referring to the outline map accompanying my paper on the Geography of the Pír Panjál, it will be seen that there are two masses of gneiss, one on either side of the valley, above and below Rámpúr, but which do not extend down into the stream itself. It is from these masses of gneiss that the boulders in the river bed have been derived; and it only remains to consider the means by which they have attained their present position.

The first of these masses of gneiss occurs a little to the south of the town of Naushara; this gneiss extends into the watershed of the mountain torrents, which descend into the Jhelam valley, so that it is quite possible for blocks of it to be carried by water into the Jhelam. Immediately below Naushara we come upon an alluvial deposit in the river, which is chiefly composed of blocks of this gneiss, which, as being harder, remains after the slate boulders from the neighbouring cliffs have been ground to powder.

At Rámpúr this alluvial formation contains gneissic blocks, some of which are as much as 15 feet in diameter; the whole formation is at least one hundred

¹ Proc. Geol. Soc., London, 1864, p. 383.

feet in thickness on the left bank of the river. The included blocks are all more or less rounded and water-worn, while the matrix in which they are imbedded is here but little stratified. As we descend the river, the blocks of gneiss continue to decrease in size, till we come upon the sharp bend in the river below Rámpúr; here a fresh stream of gneiss blocks has come down a tributary stream from the second gneiss mass in the Káj-Nág range; some of these blocks have a long diameter of upwards of 20 feet.

Still continuing our survey down the river, we find the gneiss blocks again becoming smaller and smaller, and half-way to Uri the alluvial deposit is seen to be most distinctly stratified. All the gneiss boulders have their long axes inclined up the stream and towards the river-bed at an angle of about 30°; so that one of the flat sides of each boulder is opposed to the flow of the stream, as we find to be the case in any deposit of modern river pebbles.

The summit of the alluvial formation is level, forming high-level plateaux on either side of the river. At Uri we find a similar plateau, some 200 feet in thickness, formed of the red Sirmúr rocks of the neighbouring hills; the pebbles in this deposit are rounded, and have the same relative position in regard to the stream as the gneiss blocks higher up. A few small gneiss blocks are found in the Uri deposit.

Below Uri the same formation runs along either bank of the river with the same "hanging level" often between 200 and 300 feet in thickness; a few gneiss pebbles occur in this deposit; the other boulders consist of the Sirmúr sandstones, some of them of large size.

A few miles above Hatian we again find a great number of rounded boulders of porphyritic gneiss embedded in the alluvial formation, some of which have a long diameter of over 10 feet. It is probable that these blocks have come down across the Jhelam from the peaks of the Káj-Nág immediately to the north, where the same gneiss doubtless occurs, though I do not know its correct position. Small blocks of this gneiss can be traced from Hatian as far as the bend of the river at Mozaffarábád.

It will be gathered from the above observations that the whole of the gneiss blocks in the Jhelam valley have followed the course of tributary mountain streams, have not been carried across intervening ridges, and are imbedded in an aqueous formation. Further, there are not the slightest traces of glacial action on any of the hard slate rocks in the Upper Jhelam valley, which ought to have existed, as they do in other places, had glaciers extended into the Jhelam valley.

Again, the Jhelam itself is able to roll and carry down the gneiss blocks which now lie in its course, and *a fortiori* the mountain streams with a fall ten times as great could easily have rolled them down in flood time from their original position.

At the same time, I think it extremely probable that many of these glacial blocks were carried some way down the lofty cliffs of the Panjál and Káj-Nág ranges by

ice, at a time when we know that the glaciation of the Himalayas was much greater than at present.

My only point is, that I can see no evidence of glaciers having ever extended down to the level of the Jhelam; and that the gneiss blocks could have perfectly well attained their present position by debacle action.

It will be gathered from the above observations that the Jhelam is now a denuding and not a depositing river, as it was when these alluvial formations were laid down; from which we may probably infer that great changes of level have taken place since the period of those deposits, which may have afforded greater facilities at certain times for the movements of the blocks.

In conclusion, we may state that on the mountains of the north side of Kashmir we have distinct evidence of a former glaciation at an elevation of some 6,500 feet above the sea-level, while on the south side we know of none below 8,000 feet. In the vale of Kashmir itself, and in the lower Jhelam valley, we at present have no distinct evidences of glaciation.

As far, therefore, as this negative evidence goes, it tends to disprove any former glaciation of the outer hills and Upper Punjab, because, if there had been any glaciation of the latter, there would most assuredly have been a far greater glaciation of the valley of Kashmir and the neighbouring hills, since even at equal elevations the present glaciation of the Himalaya increases as we pass towards its central axis.

CORRECTIONS TO MAP.

For "Panjtaria," read "Panjarni."

For "Sonamaro," read "Sonamarg."

INDEX.

For "Kareewahs," read "Karewahs."

For "Zogi-la," read "Zoji-la."

FURTHER NOTICES OF SIWALIK MAMMALIA by R. LYDEKKER, B. A., *Geological Survey of India.*

[WITH A PLATE.]

Since my last notice of Siwalik Mammalia,¹ another collection has been received from Mr. Theobald, and a few interesting teeth have been obtained through Mr. Blanford from Sind. Many of Mr. Theobald's specimens have added considerably to our knowledge of the dentition and osteology of previously known species. On the present occasion I shall only very briefly notice the most interesting of the majority of the new specimens, reserving their fuller description for a future occasion, when I shall have an opportunity of giving figures of them. One specimen, however—the jaw of a large monkey—is of so interesting a nature, that I have given a figure of it here, as it would otherwise have been long before I should have been enabled to do so. On the same plate I have likewise had drawn the molars of the *Macacus* and the *Rhizomys* described in my last notice.

Among the rarer specimens is the greater portion of one side of the lower jaw of *Anthracotherium punjabiense*, showing the three true molars.

PRIMATES.

PALÆOPITHECUS SIVALENSIS, n. gen. nobis.

The most interesting specimen in the whole of Mr. Theobald's Siwalik collection is the fragmentary palate of a large anthropoid ape, represented in figures 1 and 5 of the accompanying plate. This specimen is of the highest interest, because, with the exception of a single canine tooth obtained years ago by Dr. Falconer from the Siwaliks, it is the only specimen which affords us any evidence of the former existence of anthropoid apes in India, or indeed, if we except *Dryopithecus* and the smaller genera, in the whole world.

The specimen was obtained by Mr. Theobald from the Siwaliks of the Punjab, somewhere near the village of Jabi, though I do not know the precise locality; it was originally in three fragments, but two of them have been united; and as the fractures are quite recent, I presume that the specimen was broken up by the natives in extracting it from its matrix. The portion that remains shows the greater part of the right maxilla, broken near the centre of the palate, and superiorly at the zygomatic root; the second fragment is a portion of the left maxilla; in the figure the two fragments have been placed in their relative position in the proportions of the palate of the living Orang.

The fragment of the left maxilla contains the complete penultimate, and the bases of the first and last molars. The right maxilla exhibits the entire dental series, from the outer incisor to the last molar; the crown of the incisor, of the penultimate premolar, and the summit of the canine have been broken off; the penultimate molar has the centre of its crown somewhat decayed. The premolars are two in number, which shows that the specimen belongs to the Catarrhine

¹ Records, Vol. XI, p. 64.

section of the Primates; all the teeth are well worn, which shows the animal to have been adult at the time of its death.

The molars and canine are arranged in a straight line, and there is a small diastema between the canine and the outer incisor; each tooth of the molar series is inserted by four fangs. In the true molars, the last is the smallest of the three; each tooth carries four cusps on the masticating surface, which form an irregular quadrangle, arranged obliquely to the long axis of the tooth; thus, in relation to a line drawn transversely across the palate, in front of any one molar, we find the antero-external cusp placed first, then the antero-internal cusp, then the postero-external, and lastly, the postero-internal; an imperfect ridge connects the two internal cusps. The crowns of the molars are square or oblong, with their angles rounded off. The one remaining premolar carries two cusps on its masticating surface: both this and the penultimate premolar are remarkable for the shortness of their antero-posterior diameter in relation to the transverse. The canine is a short and blunt conical tooth, with the outer side of the crown rounded, and the inner side bevelled away obliquely from base to summit; no portion of the tooth which remains has been at all affected by wear. The fang of the incisor is small and laterally compressed.

The profile view of the specimen (fig. 1) shows the fangs of the molars and the root of the zygoma which arises above the interval between the first and second true molars; in front of the zygoma there is a channelled hollowing of the jaw, in front of which the fang of the canine bends round in an arch.

From the shortness and bluntness of the canine it is inferred that the jaw belonged to a female individual.

With this description, we may proceed to compare the new jaw with the jaws of other Primates. First, we shall have no difficulty in saying that our specimen does not belong to either of the genera *Semnopithecus*, *Mucacus*, or *Cercopithecus* and their allies, because in those genera the cusps on the molars are much higher and sharper, and are arranged in pairs directly transverse to the long axis of the tooth; in addition, the last molar in those genera is always as large, or larger, than the first, and the angles of the molars are square.

In *Cynocephalus* and its allies the teeth have much the same general characters as in the last group, and the last molar is much larger than the first.

As we have already seen, the Siwalik jaw cannot belong to the Platyrrhine monkeys, and there only remains, therefore, the group of the *Simiæ*, or the anthropoid apes and man to which it can belong. Now, in all the anthropoid apes and in man the molars are exactly of the pattern of those of our specimen, and there can be no doubt but that the latter belongs to this group. The molars, however, of these apes and of man are so much alike, that it is, I believe, frequently quite impossible to distinguish isolated molars, and we can only therefore arrive at specific or generic distinctions by a comparison of the whole dental series.

Commencing with the lowest of the anthropoid apes—*Hylobates*—we find that the general structure of the molars of that genus is much the same as in the

Siwalik jaw: the premolars are, however, much squarer, the canine relatively longer and sharper, and grooved and concave internally; further, the face in the Siamang is shorter, the hollow in front of the zygoma less deeply channelled, and the canine more approximated to the zygoma, and its alveolus much less arched than in the Siwalik jaw. Finally, as a character of less importance, all the species of *Hylobates* are of much smaller dimensions than the animal to which the fossil jaw belonged.

There now remain only the Orang, Chimpanzee, and Gorilla among the living anthropoid apes, with which to compare our specimen. For this comparison I have drawn up the following tables of the dimensions of the upper teeth in these animals, and in man and *Hylobates*, which it may be well to study before proceeding further.

Table showing dimensions of upper teeth in the higher Primates.

	Siwalik jaw ♀	Simia satyrus ♀	Simia satyrus. ♂	Trogodytes gorilla ♂	Trogodytes niger ♂	Human ♂ European.	Hylobates syndactylus ♂
Antero-posterior diameter of outer incisor ...	0.30	0.30	0.33	0.30	0.30	0.25	0.13
Transverse ditto of ditto ditto ...	0.19	0.23	0.25	0.25	0.26	0.18	0.18
Antero-posterior diameter of canine ...	0.53	0.46	0.68	0.80	0.62	0.34	0.36
Transverse of ditto ...	0.51	0.38	0.59	0.60	0.45	0.22	0.27
Length of molar series, ...	1.87	1.94	2.13	2.70	1.80	1.55	1.21
Ditto of premolars ...	0.58	0.70	0.74	0.90	0.61	0.50	0.43
Ditto of true molars ...	1.31	1.26	0.48	1.80	1.20	1.05	0.80
Ditto of penultimate premolar ...	0.30	0.35	0.39	0.45	0.31	0.25	0.25
Width of ditto ditto ...	0.50	0.49	0.50	0.64	0.42	0.39	0.25
Length of last ditto ditto ...	0.30	0.35	0.39	0.48	0.32	0.25	0.25
Width of ditto ditto ...	0.35	0.49	0.50	0.60	0.44	0.39	0.24
Length of 1st molar ...	0.45	0.43	0.50	0.55	0.45	0.36	0.28
Width of ditto ...	0.51	0.45	0.53	0.60	0.49	0.43	0.30
Length of 2nd molar ...	0.50	0.42	0.49	0.63	0.43	0.38	0.30
Width of ditto ...	0.51	0.48	0.53	0.60	0.49	0.43	0.31
Length of 3rd molar ...	0.41	0.42	0.49	0.60	0.35	0.35	0.28
Width of ditto ...	0.46	0.48	0.53	0.60	0.48	0.41	0.30

Table showing relative lengths of first upper true molar and last premolar in the higher Primates.

					Length of 1st molar.	Length of last premolar.	Difference between these lengths.	Proportionate length of P. M., 4 on scale of Siwalik jaw.	Excess of real over proportion- ate length.
Siwalik jaw	...	...	...	...	0.45	0.30	0.15	0.30	0.00
Human ♂	...	...	...	...	0.36	0.25	0.11	0.24	0.01
Troglodytes niger ♂	...	...	...	...	0.45	0.32	0.13	0.30	0.02
Simia satyrus ♂	...	...	...	...	0.50	0.39	0.13	0.33	0.06
Ditto ♀	...	...	...	...	0.43	0.35	0.07	0.28	0.07
Hylobates syndactylus	...	...	...	...	0.28	0.25	0.03	0.18	0.07
Troglodytes gorilla	...	...	...	...	0.55	0.48	0.07	0.36	0.12

The first of these two tables exhibits merely the absolute dimensions of the different teeth; while the second is intended to show the relative lengths of the first molar and the last premolar in the same group. In the fourth column of that table is given what would be the length of the last premolar, if that tooth bore the same relationship as regards length to the first true molar, which it does in the Siwalik jaw. From that table it will be seen that the new jaw is distinguished from the jaws of all other Primates by the relative smallness of the antero-posterior diameter of the last premolar; this shortness is in excess of what occurs in man, in which the same premolar is relatively shorter than in all the other higher Primates; next to man in this respect comes the chimpanzee, then the orang, and last of all the gorilla; and it is worthy of notice that the two species which (excepting man) exhibit the greatest variety in this respect are placed in the same genus. Professor Owen, at page 446 of his "Odontography," notices the small antero-posterior diameter of the premolars in the chimpanzee, as distinguishing it from the orang, and approximating it to man. The new Siwalik jaw, as we have seen, stands on the opposite side of man to the chimpanzee in this respect, and therefore should be still more removed from the orang. The new jaw agrees with that of the orang, gorilla, and chimpanzee, in having the molar series approximately straight, and with no indications of the horse-shoe form which occurs in the human subject; it therefore belongs to a true ape.

Turning our attention once again to the first of the two tables of measurements, we may note in what other respects the fossil jaw resembles or differs from the jaws of the orang, the chimpanzee, the gorilla, and man. In regard to

the relative length of the last molar, we find that the fossil agrees most closely with the chimpanzee and man, in both of which this tooth is much shorter than either of the other true molars. In the orang there is a very slight difference between the lengths of the first and the third true molars; in the gorilla, on the other hand, the last molar is much larger than the first. This difference in the relative lengths of the first and last molars in the gorilla, and the Siwalik jaw, together with the difference which we have already seen to obtain between the last premolars of the same, renders it evident that there is no great affinity between these two, and makes it unnecessary to carry our comparisons any further in this direction.

Comparing the dimensions of the molars of the fossil jaw with those of the female orang, we find that the true molars of the former are larger than those of the latter, and that the united length of the true molars is also greater. When, however, we take the whole molar series, we find that the five teeth of the female orang have an absolutely greater united length than the same five teeth in the Siwalik jaw, this being of course due to the small size of the premolars in the latter. In the chimpanzee, the length of the united molar series is less than in the Siwalik jaw, but the united length of the two premolars is greater, while the length of the three true molars is less: the proportions in the human jaw are in this respect nearest to the fossil.

Again, in the width (transverse diameter) of the base of the outer incisor, the fossil jaw is closer to man than to any of the large apes. In man there is no diastema between the canine and the incisor; in the orang this diastema is larger than in the chimpanzee, which in this respect approaches man. In the fossil jaw this diastema is very slightly larger than in the orang.

The dimensions of the base of the canine are considerably stouter in the fossil jaw than in either the female orang or the male chimpanzee, and approach those of the male orang and gorilla; though the shortness of the crown proves, as we said, that our specimen belongs to a female. In the female orang there is a disk of wear on the posterior border of the canine, which does not occur in the fossil specimen.

The following summary exhibits the points of resemblance and difference between the fossil jaw and the jaws of man, the chimpanzee, and the orang, which are the only three species which are closely related to it:—

MAN.

Resemblances.—Shortness of premolars; small size of last molar and of incisor.

Differences.—Straight line of teeth; large canine and diastema.

CHIMPANZEE.

Resemblances.—Straight line of teeth; shortness of premolars in a less degree; small size of last molar; large canine and diastema.

Differences.—Small incisor.

ORANG.

Resemblances.—Straight line of teeth; large canine and diastema.

Differences.—Shortness of premolars; small size of last molar; difference in wear of canine; small incisor.

It thus seems to be apparent that the fossil jaw has most points of resemblance with the chimpanzee, and that when it differs from that species it has an ultra-human character. It now remains to consider to what fossil form the jaw presents any points of affinity, and we will first direct our attention to the Siwalik Primates.

As regards size alone, the only one of the jaws of Siwalik Primates represented in Plate XXIV of the first volume of the "Palæontological Memoirs" which could possibly have any affinity to our specimen, is that of *Semnopithecus subhimalayanus* (figs. 1 and 2); the teeth of that jaw, however, and of all the specimens on the same plate, are of the semnopithecine type, and have therefore no affinity to our fossil. The same remark of course applies to the teeth of *Macacus* represented in figs. 3 and 4 of the plate accompanying this paper.

One other tooth of a quadrumanous animal from the Siwaliks is, however, described and figured by Falconer on page 304 of the first volume of the "Palæontological Memoirs;" this specimen consists of the crown of the upper canine of a large ape allied to the orang; the specimen evidently belonged to a male individual, and is somewhat larger than the canine of the male orang. Our fossil jaw, which, as we have already seen, belonged to a female, has teeth somewhat larger than those of the female orang; there is therefore every probability that Falconer's canine and our new jaw belonged to the same species.

Turning, now, to the fossil quadrumanous animals of Europe, the only three genera with which I am acquainted which are likely to have any affinity to our specimens are *Mesopithecus*, *Pliopithecus*, and *Dryopithecus*.

Mesopithecus, from the Pikermi beds,¹ is of small size, and is regarded as being intermediate between *Hylobates* and *Semnopithecus*; the teeth are, however, distinctly of the semnopithecine type, and consequently quite different from those of our fossil.

Pliopithecus,² from the Miocene of France and Switzerland, is also of small size, and resembles *Hylobates* so closely, that it is referred by Professor Rutimeyer to that genus.

Dryopithecus,³ from the Miocene of France, is an ape of larger size, which is, I believe, only known from the lower jaw and some limb-bones, and which from the small size of the canine and diastema is regarded as having an affinity to

¹ "Animaux fossiles et Géologie de l'Attique," Gaudry, Pl. I.

² Lartet: "Comptes Rendus," Vol. 3, p. 222, and plate. Heer: "Primæval World of Switzerland," Vol. II, p. 82, Pl. XI.

³ Lartet: sup cit. Owen, "Palæontology," p. 383.

man. The antero-posterior extent of the second premolar, according to Professor Owen, is, however, greater than in the chimpanzee, and therefore still greater than in the Siwalik fossil; the latter, however, agrees with *Dryopithecus* in having narrow incisors.

Reviewing the whole of the foregoing facts, it does not appear that our fossil jaw agrees precisely with the jaw of any known living or fossil anthropoid ape, though it seems to make the nearest approach to that of the chimpanzee, and also shows some points of affinity with the jaws of man, *Dryopithecus*, and the orangs. The resemblance between the Siwalik jaw and that of the chimpanzee does not, however, appear to me to be so close as to warrant our classing the two under the same genus, because, with the very marked difference which occurs in the relative dimensions of the last premolars in the two jaws, there is every probability that equally well marked differences existed between the crania of the two animals. It must, however, be again borne in mind that the chimpanzee and the gorilla, which present such difference in the form of this tooth, are classed in the same genus.

Since I do not think that we are justified in referring the Siwalik jaw to any known genus, I propose to form for it the new generic name '*Palaopithecus*,' with the specific affix of '*sivalensis*.'

I can only hope that on some future occasion we may be fortunate enough to come across the cranium of this most interesting relic of the past, when we shall be able with some approach to certainty to assign to it its exact affinities, which with our present meagre specimens we can only vaguely guess at. We can only say that there lived in the Siwalik period of India, a huge anthropoid ape intermediate in size between the orang and the gorilla, the males and females of which were provided with canines exceeding in size the other teeth, and that those of the former bore about the same proportion to those of the latter as we find prevailing in the living anthropoid apes. Further, in the form of its teeth, this ape was nearest to the chimpanzee; but in the points in which it differed from that species, it shows great resemblances to the teeth of man.

I will conclude this notice with a few general considerations regarding the past and present distribution of the anthropoid apes. If this distribution in time and space be tabulated, as is done in the accompanying note,¹ it will, I think, be apparent that such living and fossil anthropoid apes as we are now acquainted with are merely a few from a large number of species which once existed on the earth.

			Miocene.	Pliocene.	Recent.
¹ <i>Troglodytes</i>	...	...	...	...	W. Africa.
<i>Simia</i>	...	...	...	...	Borneo and Sumatra.
<i>Palaopithecus</i>	...	...	...	N. India.	
<i>Dryopithecus</i>	...	...	W. Europe.		
<i>Hylobates</i>	...	...	...	...	Malaya, Assam, and China.
<i>Pliopithecus</i> (= <i>Hylobates</i> ?)			W. Europe.		

Further, it seems hardly to admit of doubt that three such closely allied genera as *Troglydites*, *Puleopithecus*, and *Sinia* must have had a common parentage and a common ancestral home. For three tropical or sub-tropical genera inhabiting respectively Western Africa, Northern India, and Sumatra and Borneo, the unknown common home may have possibly been situated in the Indian Ocean, being in fact the hypothetical sunken southern continent, whether it be called 'Lemuria,' 'Indo-Oceania,' or what not, to the former existence of which so many separate lines of evidence point. This vanished land was probably once the common home of the African and Indian ostriches,¹ which must have had a common centre of dispersion. Here also we may possibly look for the old home of the *Munis* of Siwalik and modern India, and of modern Africa.

If this hypothetical sunken southern continent² was the centre of dispersion of the anthropoid Primates, it is not improbable, nay rather it is almost certain, that numbers of species and genera must have lived and died, and finally become extinct, on that continent, and that only some of their descendants reached the borders of that continent—in other words, Africa, India, and Borneo. If this be so, it is probable that all records of some anthropoid Primates have long since, and for ever, been entirely removed from human cognizance, while it is possible that among these may have been forms nearer to man than any of those of which we have any records. On this supposition it is possible that we may never discover the "missing links." On the other hand, we have in the tropical countries which border the Indian Seas the probable periphery of this sunken continent, and it is among the unexplored tertiaries of these countries that we may yet hope to find fossil forms of *Primates*, which may tend to bridge the great gulf which now exists between the highest known ape and man. Of these countries, the geology of Africa and Sumatra and Borneo is virtually unknown. In India only a few scattered localities have hitherto yielded mammalian remains, and remains of Primates are of extremely rare occurrence in them. Thus, in the much-worked Siwaliks we only know of two specimens of the remains of anthropoid apes, which have been discovered at an interval of many years apart, among thousands of specimens obtained. There is, therefore, no reason to assume that other forms of anthropoid apes did not exist in that period. In Central and Southern India, with the exception of the little known Perim beds, we have no equivalents of the Siwaliks; and there is here therefore abundant room for older Primates to have existed without our having the least knowledge of them.

In the newer Nerbudda group scarcely any small fossils have been collected; and yet there is an absolute certainty that many forms of Primates

¹ *STRUTHIO ASIATICUS*, M.-Edwards, "Oiseaux Fossiles de la France," Vol. II, p. 587, and article in present number.

² Mr. Wallace ("Tropical Nature," p. 329) has come to the conclusion that "Lemuria" never existed, or that it at all events must have disappeared before the miocene. There appears to me, however, to be a great weight of evidence in favor of a former land connection between the continents of the old world, though this connection may very possibly have disappeared in comparatively early Tertiary times.

must have existed at that time, many of which were probably distinct from living species.

Our knowledge, therefore, of the tertiary faunas of the Tropics and Sub-Tropics is really extremely slight; and until this slight knowledge has been amplified by the fullest explanation of every tertiary rock stratum in Africa, India, and Malaya, no one is entitled to assert that man and the anthropoid apes had no common ancestor, because no such ancestor has hitherto been discovered; and even if such exploration were made without results, there remains the hypothetical sunken southern continent, with the disappearance of which may also have disappeared the "missing links."¹

Finally, one other lesson is to be learnt from the Siwalik ape. We know that the living anthropoid apes dwell only in the deepest gloom and solitude of primeval forests, where vegetation grows luxuriously, and offers a constant supply of fruits throughout the year. From this we may probably infer that the Siwalik ape inhabited a similar forest-clad country, and that, consequently, the present Siwalik area of the Punjab was in parts at all events clothed with forests in which dwelt the *Palæopithecus*, instead of being, as now, a sun-scorched and somewhat desolate region. Evidence of the former existence of these forests is, as I have previously remarked,² afforded us by the occurrence of numbers of fossil tree-stems in various parts of the Siwaliks.

MACACUS SIVALENSIS, nobis.

In figs. 2 and 4 of the accompanying plate are represented the two fragmentary upper jaws of *Macacus sivalensis*, which were described by me on page 66 of the last volume of the "Records," and which, therefore, need no further notice on the present occasion.

RODENTIA.

RHIZOMYS SIVALENSIS, nobis.

The specimen drawn in fig. 3 of the same plate is a fragment of the left ramus of the mandible of the *Rhizomys* described by me at page 100 of the last volume of the "Records," and which I then considered to belong in all probability to a new species. The first molar has been broken away in the specimen but the second and third molars are in excellent preservation; the greater part of the incisor is seen on the inferior border.

PROBOSCIDA.

DINOTHERIUM INDICUM, Falc.

A detached first lower true molar of a *Dinotherium* has been obtained through Mr. Blanford from the Laki Hills of Sind, which is larger than and of different shape from the corresponding tooth in the lower jaw of *Dinotherium*

¹ See an article on this subject in the Quarterly Journal of Science for October 1878.

² Rec. Geol. Surv. India, Vol. IX, p. 100.

pentapotamiæ from Sind, noticed at page 75 of the last volume of the "Records", and which agrees so exactly, as regards dimensions, with the base of the corresponding tooth in the lower jaw of *D. indicum* from Perim Island represented in fig. 6 of plate 35 of the "Fauna Antiqua Sivalensis," that I have considered it to belong to that species.

The tooth is considerably worn, and carries three equal sized transverse ridges, which show no sign of a median longitudinal division, which, with the bluntness of the ridges, shows that the tooth did not belong to a *Trilophodont Mastodon*. The tooth is relatively narrow in proportion to its length, which shows that it belongs to the lower jaw, while the greater elevation of the inner side of the ridges shows that it belonged to the left side. On the outer and posterior sides of the tooth there is a large thick cingulum.

I have given below the dimensions of this tooth, together with those of the corresponding tooth of *D. giganteum* in the large Eppelsheim cranium, and of the corresponding tooth in the above-mentioned jaw of *D. pentapotamiæ* :—

				New tooth.	<i>D. giganteum</i> .	<i>D. pentapotamiæ</i> .
Length of tooth	...	...	...	3·9	3·5	2·35
Width of 1st ridge	...	...	...	2·5	2·6	1·8
„ of 2nd „	...	...	...	2·5	2·6	1·8
„ of 3rd „	...	...	...	2·4	2·2	1·7

The tooth is slightly larger than the corresponding molar of *D. giganteum*, in which it agrees with Falconer's fragment, and is far too large to have belonged to *D. pentapotamiæ*; it is further distinguished from the same tooth in both those species by the presence of the large cingulum.

If now we turn to the description of the above-mentioned jaw of *D. indicum* on page 407 of the first volume of the "Palæontological Memoirs,"¹ we shall find that the dimensions of the base of the crown of the first true molar are as follows—length 4, width 2·8; these dimensions agreeing very closely with those of our new tooth. The latter further agrees with a fragmentary tooth of *D. indicum* from Perim Island, described by Dr. Falconer at page 397 of the first volume of the "Palæontological Memoirs," in the great thickness of the enamel, which in both measures 0·25 inch; in *D. pentapotamiæ* and *D. giganteum* the enamel is much thinner. Although, therefore, the perfect corresponding tooth of *D. indicum* is unknown, I think on the above grounds I am justified in referring the new tooth to that species. This identification is of great importance in connecting the horizon of the Perim Island and Sind rocks as I shall have occasion to note more fully below.

A portion of another tooth of a large *Dinotherium* has been received among a collection made by the late Dr. Verchere, which appears to have come from

¹ P. 397.

Dera Ghazi Khan, and which seems undoubtedly to belong to the same species. The specimen consists of the last ridge of a third upper molar of the left side, but very little worn. Its dimensions are given below, together with those of the second upper molar of *D. pentapotamiæ*, described at page 55 of the second fasciculus of the tenth series of the "Palæontologia Indica," and also with those of the same tooth of *D. giganteum* :—

			<i>D. indicum.</i>	<i>D. giganteum.</i>	<i>D. pentapotamiæ.</i>
Width of last ridge ...	...	...	3·7	3·4	2·3
Thickness of base of ridge ...	...	...	1·8	1·6	1·1

The new tooth differs from the figured specimen of *D. pentapotamiæ* in having no ledge on the hinder side of the last ridge, and in the ridge itself being somewhat less curved; it agrees with the other teeth of *D. indicum* in having very thick enamel, and being slightly larger than the corresponding tooth of *D. giganteum*; there is a tubercle on the inner side of the transverse valley.

NEW SPECIES OF DINOTHERIUM.

In addition to *Dinotherium indicum* and *D. pentapotamiæ*, we have now evidence of a third species of Indian species of the genus. The specimen from which this evidence is derived consists of a portion of the lower jaw, containing the two last molars, collected by Mr. Fedden in Sind. The jaw and teeth are much smaller than those of *D. pentapotamiæ*; the characteristic point of the jaw is, however, its cylindrical form, in which respect it differs from all other species of the genus.

GENUS MASTODON.

Of the genus *Mastodon*, Mr. Theobald's last collection contains a great number of specimens of the jaws and teeth, some of which are of great interest, and add considerably to our knowledge of these animals. A few of the most interesting specimens are noticed here cursorily, as it will be a long time before I shall be able to describe them in detail.

MASTODON PANDIONIS, Falc.

The first specimen in this collection which calls for especial notice is a portion of the mandible of a *Mastodon*, which cannot be referred to any of the previously known Siwalik species. The specimen comprises a portion of the horizontal ramus with two molars, and the symphysis of the mandible; the intermediate portion of the specimen was also discovered, but unfortunately crumbled to dust during its transit down country. The most noticeable portion of this jaw is the symphysis, of which the part now remaining has a length of 22 inches; this part is laterally compressed, and on its upper surface is excavated by a large groove upwards of 5 inches in depth at its proximal extremity.

The one complete tooth in this jaw carries four transverse ridges and a hind talon; its length is 8·5, and its width 3·7 inches; this tooth is the last true molar, and the jaw therefore belongs to a *Trilophodon*. The crown of the penultimate

molar is unfortunately broken away, but from the small size of its base, I imagine that it could only have carried three ridges. The last molar has a very deep longitudinal valley, which divides each transverse ridge into a distinct outer and inner column; large accessory columns are placed in the valleys, which are in consequence completely blocked. The disks of wear of the columns form irregular circles; the tooth has some resemblance to some varieties of the molars of *M. sivalensis*, in which the alternate arrangement of the columns is less pronounced than usual; the last molar of the latter has, however, five or six ridges. When complete, the distal extremity of the mandible must have been at least 30 inches in advance of the last molar.

There are no tusks in this specimen; among Mr. Theobald's collection, however, there is the distal extremity of an elongated mandibular symphysis of a species of *Mastodon*, which carries portions of two very large tusks. This mandibular rostrum cannot belong to any of the described species of Siwalik *Mastodon*; and as it agrees in form with the last specimen, I consider it probable that both belonged to the same species; the tusked jaw being that of a male, and the tuskless that of a female individual. The fragments of tusks remaining in the specimen are only some 10 inches in length; they are much compressed laterally, the transverse section being pear-shaped, having the thinner end upwards. The inferior border of the fragments is convex, and the superior border concave; the vertical diameter is 3.2 inches, and the transverse diameter at the thickest part 1.11 inches.

Another specimen of the mandible of a trilophodont *Mastodon* broken off at the symphysis, carries two molars, which are respectively the penultimate and last. The second of these teeth agrees precisely with the corresponding tooth of the last specimen of the mandible, but being less worn, is more suitable for description; the identity of these teeth shows that the two mandibles belonged to the same species. The penultimate tooth in the second mandible carries three ridges and a hind talon, which proves that the first jaw belongs to a *Trilophodon*. In these teeth each ridge is divided by a longitudinal channel into an inner and an outer column; each outer column gives off an accessory column from either side, which together project obliquely into and quite block the transverse valleys. The whole arrangement of the columns on the outer side form a zigzag arrangement; while the summit of each column wears into a circle.

Now, the only two known Indian trilophodonts are *M. falconeri* and *M. pandionis*; the molars of the former I have not yet been able to describe. The penultimate lower molar of that species is, however, much larger than the same tooth in our new specimens, and has nearly open valleys, with distinct and clear ridges, whose summits wear into trefoils and not into circles. I shall hope shortly to be able to show by a figure the complete distinctness of these two teeth. The jaws of the two are further very different—that of *M. falconeri* being thick and rounded, while the present specimens are thin and flat.

Of *M. pandionis* a description of the penultimate upper molar will be found at page 124 of the first volume of the "Palæontological Memoirs of Dr. Fal-

coner"; if the description of that tooth be compared with that of the corresponding lower tooth noticed above, it will be seen that the two agree precisely, except that one is the reverse of the other, as is always the case in upper and lower molars. I have therefore no doubt but that these new jaws belong to *M. pandionis*, which was consequently a species provided with a long spatulate mandible, and of which the male carried inferior tusks.

The interest of this discovery of *M. pandionis* in the Siwaliks is very great; the other known teeth are said to have been obtained from the Deccan from deposits supposed by Falconer¹ to be of pliocene age; wherever they came from, it is now probable that they belong to the same period as that in which lived the other animals of the Siwalik fauna. In cataloguing the fossil *Proboscidea* in the Indian Museum, I have lately come across a last milk-molar of a trilophodont *Mastodon* from Perim Island which seems undoubtedly to belong to the same species.

In treating of *M. pandionis* at page 124 of the first volume of the "Palæontological Memoirs," Dr. Falconer remarks on the great similarity of the general plan of the teeth of *M. pandionis* and *M. angustidens*, the plan of the former being, however, rather the more complex of the two. It is interesting to observe how this similarity of plan in the structure of the teeth extends into as much as we know of the osteology of the two animals; thus the newly discovered specimens reveal to us that both the species were furnished with a long spatulate symphysis to the mandible, tuskless in the female, but in the male provided with a pair of relatively large and slightly curved tusks. From this similarity in structure we may, I think, infer that these two species of *Mastodon* were very closely related to one another, and that it is not impossible that at no relatively distant epoch they must have had a common parentage. One very important difference, however, exists in the structure of the teeth of the two species, which is that in *M. pandionis* (though this is not mentioned in Falconer's specimen) there is a large quantity of cement in the valleys, which is entirely wanting in the molars of *M. angustidens*.

MASTODON PERIMENSIS, Falc. & Caut.

Two very interesting points in relation to the dentition of this species are shewn among Mr. Theobald's last collection; one of them is, that this species, like *M. latidens*, was provided with an ultimate upper premolar, and the other that the species carried tusks in the mandible. The specimen proving the existence of an upper premolar consists of a portion of the left maxilla containing two teeth; the hinder of these teeth is $4\frac{1}{2}$ inches in length, carries four transverse ridges, and small fore-and-aft talons; the anterior tooth has not yet come into wear, being only in germ, and having its masticating surface on a level with the base of the crown of the hinder tooth, which proves it to be a premolar, which has only just displaced the milk-molar which it has succeeded.

¹ Pal. Mem., Vol. II, table, p. 14.

The premolar is rounded, and carries two transverse ridges and two small talons. The larger tooth corresponds exactly in form with the first or antepenultimate molar of *M. perimensis* from Perim Island, represented on plate 9 of the first volume of the "Paleontological Memoirs of Dr. Falconer," and which is now in the Indian Museum. Mr. Theobald's specimen is, however, rather the smaller of the two. From the large size of the premolar in the new jaw, I think that that tooth must be the last, and that the tooth which it has replaced must consequently have been the last milk-molar; the second tooth will consequently be the first or antepenultimate true molar, and will correspond to the above-mentioned specimen of Falconer's: the slight difference in size of the two specimens is very probably due to difference of sex.

I have already mentioned at page 71 of the last volume of the "Records" the discovery of a complete mandible of this species, and of the possible occurrence of lower tusks. Two specimens of the symphysis of the mandible of the same species in Mr. Theobald's last collection have now made it certain that certain individuals, probably males, were furnished with small mandibular tusks. Both the new specimens have been fractured, and exhibit sections of the tusks in their alveoli; these tusks were of small size, and show an oval cross-section, of which the vertical diameter in the middle of the symphysis is 1·6 inches, and the transverse diameter 1·3.

PERISSODACTYLA.

ACEROTHERIUM PERIMENSE, Falc. & Caut.

The discovery of a nearly complete cranium of this species in the Siwaliks of the Punjab by Mr. Theobald is of great interest, as only very fragmentary remains of the species have hitherto been known. The new cranium is further interesting, as showing the accuracy of Falconer's opinion (formed on the evidence of a few generally imperfect teeth), that the Perim Island Rhinoceros was hornless, and belonged to the genus *Acerotherium*.

The cranium, with the exception of a few minor injuries, only lacks the extremity of the nasals, and maxillæ and premaxillæ, together with the greater part of the zygomatic arches, to be complete, and is generally in a very excellent state of preservation. As I shall hope on a future occasion to give a figure and a more detailed description of this cranium, it will only be noticed very shortly here.

The cranium is that of a fully adult animal, the permanent molars being greatly worn down, and the cranial sutures mostly obliterated; it is also of huge dimensions. It is at once distinguished from the three species of true Siwalik Rhinoceros, of which figures of the cranium are given in the "Fauna Antiqua Sivalensis" by its straight profile, in place of the highly curved profile which characterizes the other species. It is further distinguished by the very small size of the nasals: these bones are unfortunately broken off near their base, but sufficient of them remains to show that they formed merely a short conical pro-

jection, having no resemblance to the broad and curved bones which occur in the other species. The transverse diameter of the base of these bones in the new cranium is only 3·3 inches, whereas in the smaller crania of *R. sivalensis* and *R. palæindicus* it is 5 and about 4·8 inches respectively, and in the large *R. platyrhinus* is upwards of 6·5 inches. Again, the base of the nasals in the new cranium is perfectly smooth even on the upper surface, shewing that there was no nasal horn, such as exists in the other species; the frontals are also perfectly smooth, and shew no signs of having ever carried a horn. The cranium, therefore, is truly that of an *Acerotherium*, and as such quite distinct from the other Siwalik species of Rhinoceros.

Together with this cranium, Mr. Theobald has sent the less worn upper dentition of another individual of the same species, which is in a better state for comparison than the more worn dentition of the cranium. The antepenultimate upper premolar in both these specimens agrees exactly with the corresponding tooth represented in fig. 15 of plate 75 of the "Fauna Antiqua Sivalensis," which is the type of *A. perimense*; the true molars in Mr. Theobald's specimens also agree with the fragmentary molars of the same species represented on the same plate; the new cranium may, therefore, be safely referred to *A. perimense*.

This being so, the complete dentition of this species now enables me to correct a very serious error into which I had fallen, and through which I had been led to form a new species of Siwalik Rhinoceros, (*R. planidens*), though working with imperfect materials.

If we turn to figures 7 and 8 of the second part of the tenth series of the "Palæontologia Indica," it will be found that I figured two imperfect upper molars of a Rhinoceros, which I considered to be different from the corresponding teeth of any other species, and which I accordingly referred to a new species under the name of *R. planidens*. Subsequently several complete upper molars, and a considerable portion of a mandible, together with an upper incisor, all of large size, were obtained by Mr. Theobald, and were referred to under the same specific name at page 96 of the last volume of the "Records."

Now, the true molars in Mr. Theobald's two latest specimens agree precisely with the above-mentioned upper molars, and clearly belong to the same species. It is therefore clear that the new species *R. planidens* must be merged in *A. perimense*.

In figure 5 of Plate VI of the same volume of the "Palæontologia Indica" I figured two teeth of *A. perimense*, which I considered to be the last premolar and the first true molar, because, as will be seen by the figure, the second of these two teeth is the most worn. Considering this latter tooth to be a true molar, it was apparent that the true molar referred to *R. planidens* could not belong to *A. perimense*. A comparison of the two teeth in question with the dentition of Mr. Theobald's specimens shows, however, that these teeth are really the first and second premolars, and that their relative rate of wear must be an abnormality. I may add that I ought to have known that these two teeth must

have been the two middle premolars, because no such discrepancy in size occurs between the last premolar and first true molar as occurs between these two teeth, while the smaller tooth is of too small dimensions to have been the last true molar. I may add that the tooth represented on Plate VI, figure 2 of the above referred to volume of the "*Palæontologia Indica*," as the first true molar of *A. perimense*, is really the penultimate premolar; and that the unnamed tooth from Sind, represented on figure 6 of the same plate, seems to be the antepenultimate upper premolar of the same species.

On a future occasion I shall hope to be able to give figures of the almost complete upper and lower dentition of the present species; and I cannot but regret that I have previously published figures of such very imperfect specimens. It is interesting to observe that *A. perimense* agreed with the European *A. incisivum*, in being hornless, and in being furnished with a single pair of very large upper and lower incisors, clearly showing that the absence of one weapon of offence or defence is compensated for by the greater development of another.

I may here mention that we seem to be gradually obtaining evidence that the mammalian fauna of the Punjab and Sind forms a connecting link between the fauna of Perim Island on the one hand and of the more eastern Siwaliks on the other. Thus, as will be gathered from a perusal of this and my previous papers in the Records, we have in the Siwaliks of the Punjab and Sind the following Perim Island mammals, which were not known to Falconer from the more easterly Siwaliks, *viz.* :—

- Dinotherium indicum.* P.; I. P. S.
- Mastodon pandionis.* P.; I. P. Deccan (?)
- Mastodon perimensis.* P.; I. P. S. (?)
- Hyotherium sindiense.* P.; I. S.
- Acerotherium perimense.* P.; I. P. S. (?)
- Hippotherium theobaldi.* P.; I. P.

All these mammals belong to old forms, and seem to indicate that the Perim Island deposits and the zone in which they occur in the Punjab (position unknown) are low down in the series and correspond to the older Sind Siwaliks.

Distribution of genera of Siwalik Mammals.

Since the publication of my paper on the "*Fossil Mammalian Fauna of India and Burma*,"¹ several new genera have been added to these fauna, and the distribution of the previously known genera has been further elucidated. I have therefore compiled the following table of the distribution of the mammalian genera in the Siwalik and the other tertiaries below the Nerbudda group, which must be taken as superseding the tables given on pages 90-92 of my above quoted memoir.

¹ Rec. Geol. Surv. Ind., Vol. IX, pt. III.

Table of distribution in India of Siwalik Mammalian Genera.

Order.	Genus.	Burma.	Sylhet.	Country east of Jhelam R.	Punjab west of Jhelam R.	Sind.	Perim I.
PRIMATES	Palæopithecus	...	...	×	×	...	...
	Semnopithecus	...	...	×	...	...	...
	Macacus	...	...	×	×	...	...
PROBOSCIDA	Dinotherium	...	...	...	×	×	×
	Mastodon	×	...	×	×	×	×
	Stegodon	×	×	×	?	...	...
	Loxodon	...	...	×	...	...	...
	Euelephas	...	...	×	...	...	...
UNGULATA	Sus	...	×	×	×	×	×
<i>Artiodactyla</i>	Hippohyus	...	...	×	×	...	×
	Tetraconodon	...	...	×	×	...	...
	Hippopotamus	×	...	×	?	...	...
	Sanitherium	...	...	...	×	...	...
	Listriodon	...	...	...	×	?	...
	Hyotherium	...	...	...	...	×	×
	Anthracotherium	...	×	...	×	×	...
	Hemimeryx	...	...	...	...	×	...
	Sivameryx	...	...	...	...	×	...
	Hyopotamus	...	...	...	...	×	...
	Choeromeryx	...	×	...	...	...	...
	Merycopotamus	×	...	×	×	...	...
	Chalicotherium	...	...	×	...	×	...
	Camelus	...	...	×	...	...	...
	Sivatherium	...	...	×	...	...	...
	Hydaspitherium	...	...	...	×	...	...
	Vishnutherium	×	...	...	?	...	...
	Bramatherium	...	...	...	...	...	×
	Camelopardalis	...	...	×	×	...	×
	Antelope	...	...	×	×	...	×

Order.	Genus.	Burma.	Sylhet.	Country east of Jhelam R.	Punjab west of Jhelam R.	Sind.	Perim I.
<i>Artiodactyla</i> — <i>contd.</i>	Bos ...	?	...	×	...	...	...
	Hemibos ...	...	...	×	?	...	...
	Amphibos ...	...	...	×	?	...	...
	Peribos ...	...	...	×	...	...	...
	Bubalus ...	...	...	×	..	...	...
	Bison ...	...	...	×	...	...	...
	Capra ...	...	...	×	×	...	×
	Dorcatherium ...	...	...	×	×	...	...
	Cervus ...	?	×	×	×	...	...
<i>Perissodactyla</i> ...	Acerotherium ...	?	...	?	×	×	×
	Rhinoceros ...	×	...	×	×	×	?
	Hippotherium ...	...	...	×	×	...	×
	Equus ...	?	...	×	...	...	...
CARNIVORA ...	Hyænarctos ...	...	...	×	×	?	...
	Ursus ...	?	...	×	...	...	...
	Mellivora ...	...	...	×	×	...	...
	Meles ...	...	...	...	×	...	...
	Amphicyon ...	...	...	×	×	×	...
	Enhydriodon ...	...	...	×	..	...	...
	Lutra ...	...	...	×	×	...	...
	Canis ...	...	...	×	?	...	...
	Ictitherium ...	...	...	...	×	...	...
	Hyæna ...	...	...	×	×	...	...
	Machairodus...	...	...	×	...	...	...
	Felis ...	...	...	×	×	...	...
	Pseudæurus...	...	...	...	×	..	...
RODENTIA ...	Hystrix ...	...	...	×	×	...	...
	Rhizomys ...	...	...	?	×	...	...
	Mus ...	...	...	×	...	...	...
EDENTATA ...	Manis ...	...	...	...	...	×	...

In the above table there are a few points which call for short notice. In the first place, the number of specimens collected from Sylhet is so small, that no inference as to the absence of genera from the formations of that district can be drawn from their absence in the table: to a less degree the same remark applies to Burma and Perim Island. Again, in the three columns headed respectively

Country east of Jhelam R.," "Punjab, west of Jhelam R.," and "Sind," I do not wish to lay any great stress on the absence in any of these columns of any of the rarer genera, such as *Sanitherium*, *Amphicyon*, or *Lutra*, as indicating their absence from the formations under those columns. On the other hand, the presence or absence in any of these columns of any of the common genera, such as *Euelephas*, *Merycopotamus*, *Bos* or *Equus*, is of great weight, and is to be considered in many cases as a fact in distribution.

We may notice in Sind the complete absence of the following common Siwalik genera, viz., *Stegodon*, *Loxodon*, *Euelephas*, *Hippopotamus*, *Merycopotamus*, *Camelus*, *Camelopardalis*, *Bos*, *Bison*, and *Equus*; and we may further note that most of these genera are modern forms, and that most of them are not found in the country to the west of the river Jhelam, but that they occur commonly enough in the country to the east of that river. Again the genera *Dinotherium*, *Listriodon*, *Hyotherium*, various *Suina*, *Hyopotamus*, and *Acerotherium*, are of fairly common occurrence in Sind and the Punjab, and do not, I believe, occur in the country to the east of the Jhelam, with the exception perhaps of *Acerotherium*, which has been found a little to the east of that river. Again the genus *Equus*, which is extremely common in the Siwalik country of Falconer, is unknown in the Western Punjab, and is there replaced by *Hippotherium*, of which genus at least two species occur there very commonly, of which one (*H. artilopinum*) occurs in the more eastern country, while the other (*H. theobaldi*) is only known from the Western Punjab and Perim.¹

The table in fact shows that the more modern genera are mainly characteristic of the country to the east of the Jhelam, while the Punjab, Sind, and Perim Island are characterized by an older facies of genera,—the greater number of old genera occurring in Sind. The Sind fauna is consequently to be regarded as the oldest of the Siwalik group, that of the Punjab and Perim Island probably the next in age, and the Siwaliks of the Delhra Dûn and neighbouring country as the newest of all. I wish, however, to add that although I think the difference in the mammalian faunas of the different districts under discussion are due in great measure to differences in relative age, yet that it is probably that many of the genera, such as those of the *Sivatheriidae*, were strictly contemporaneous, and were limited in their geographical range.

¹ In Falconer's catalogue of the *Vertebrata* in the collection of the Asiatic Society of Bengal, the molars of this species are referred to *Equus*. I believe I have evidence of the existence of four species of the genus in the Punjab.

DESCRIPTION OF PLATE.

- Fig. 1. *PALÆOPITHECUS SIVALENSIS*, nobis.
Lateral view of right maxilla.
- „ 2. *MACACUS SIVALENSIS*, nobis; palatal view of right maxilla.
- „ 3. *RHIZOMYS SIVALENSIS*, nobis; palatal view of left ramus of mandible.
- „ 4. *MACACUS SIVALENSIS*, nobis; palatal view of left maxilla.
- „ 5. *PALÆOPITHECUS SIVALENSIS*; palatal view of specimen represented in fig. 1.

Fig. 3 twice the natural size; the rest natural size. The two sides of the maxilla represented in fig. 5 have not been placed quite symmetrically. The perfect tooth on the left side of the figure should be opposite the decayed tooth on the right side.

NOTES ON SOME SIWALIK BIRDS, by R. LYDEKKER, B. A., *Geological Survey of India.*

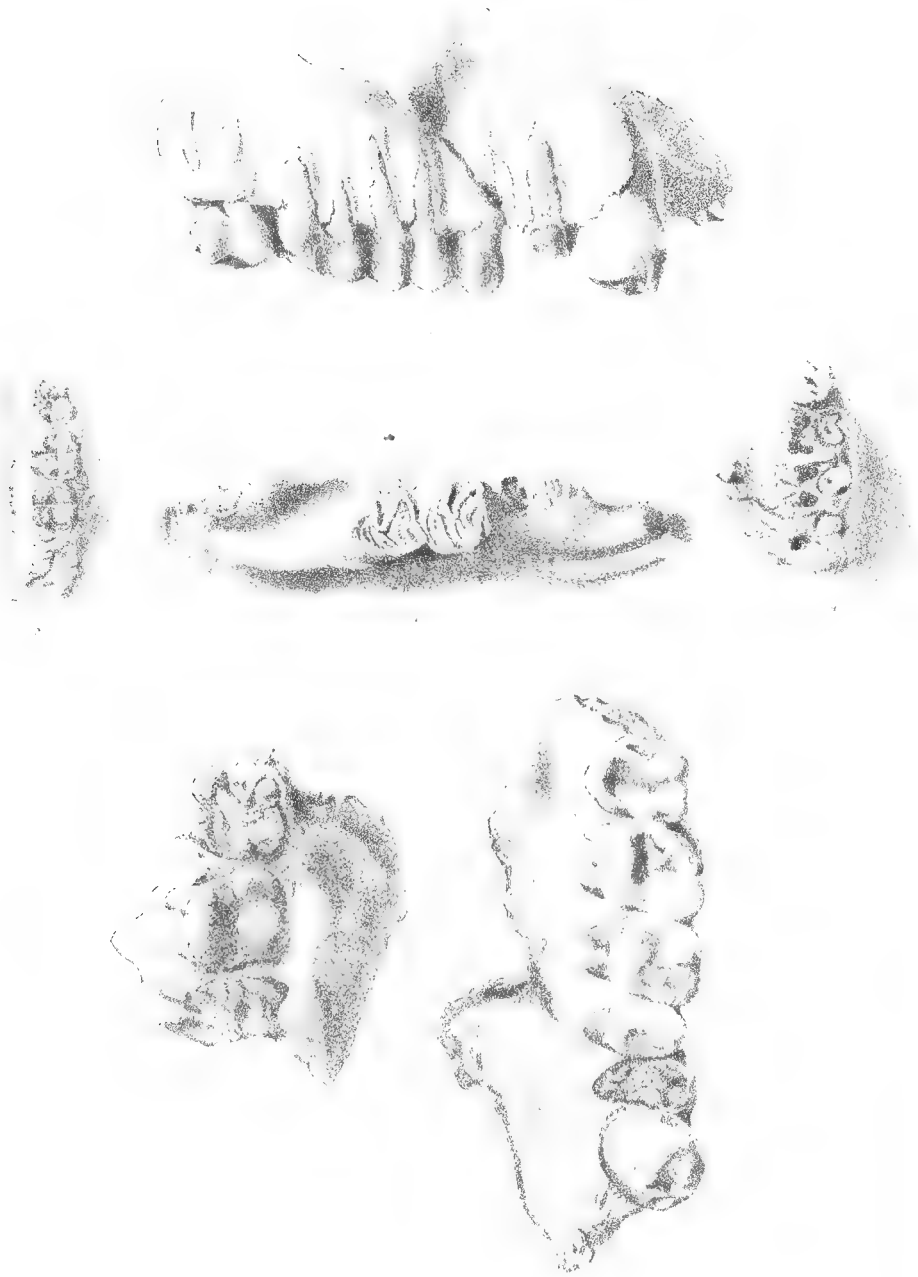
INTRODUCTION.

In the Siwaliks, as in many other ossiferous formations, the fossil remains of birds are of extremely rare occurrence, and such bones as do occur are generally, owing to their delicate structure, merely fragments of the stouter extremities. Except in formations like the lithographic slates of Solenhofen, the skull of birds are scarcely ever preserved as fossils, and none have as yet been obtained from the Siwaliks. From time to time, however, a few fragments of bird-bones have been obtained from these deposits, and these are of extreme interest, as being the only evidence we have at present of the existence of an avian fauna in the Siwaliks. Some of these bones were collected by Dr. Falconer, and were deposited by him in the British Museum, figures being given of them on Plate R of the unpublished plates of the “*Fauna Antiqua Sivalensis*.”¹ On the evidence of these bones M. A. Milne-Edwards² established two species of extinct Siwalik birds, namely, *Struthio asiaticus* and *Argala falconeri*. From the evidence of another bone which is not figured in the “*Fauna Sivalensis*,” the same writer considered, that a bird allied to *Phaëton* must have lived with the Siwalik fauna.

Among the vast collection of mammalian and reptilian bones obtained by Mr. Theobald from the Siwaliks, there are a few fragmentary bird bones; and these together with the bones collected by Dr. Falconer, form mainly the subject of the following short notes. These notes are not intended as an accurate description of the bones, because I wish to defer that description in the hope that I may hereafter obtain more complete materials. Some of the bones are, however, of such interest, that I have thought it well to bring their existence into notice, without deferring them to the indefinite period when I shall be enabled to give figures of them.

¹ Photographic copies of these plates can now be obtained at the British Museum.

² Oiseaux fossiles de la France, Vols. I, p. 449, II, p. 587.



FOSSIL STRUTHIOIDS.

With regard to *Struthio asiaticus* of M. Milne-Edwards, it appears that this species was formed on the evidence of the phalange, and of the distal extremity of the tibio-tarsus, which are represented in figs. 2 and 15 of the above-quoted plate of the "Fauna Antiqua Sivalensis." In noticing these species, M. Milne-Edwards (*loc. cit.*) remarks: " *L'une des espèces les plus remarquables appartenait au groupe des Brévipennes et se rapprochait beaucoup de l'Autruche d'Afrique par la conformation de son pied, qui ne portait que deux doigts.*" I am rather at a loss to discover how M. Milne-Edwards determined that his Siwalik ostrich had but two toes, because, as I have said, the only struthioid bones figured in the "Fauna Antiqua Sivalensis" are the distal extremity of the tibio-tarsus and a phalange. The first bone would, as far as I am aware, give no indication of the number of toes, and the second, which appears to belong to a median digit, is symmetrical in itself, and might, as far as I can see, belong to either a two- or a three-toed bird. It is, however, possible that M. Milne-Edwards may have seen a specimen of the tarso-metatarsus of this struthioid which would of course settle the question. In any case it is probable that such an authority on the subject as M. Milne-Edwards would not have made such a positive assertion without good grounds; and I therefore adopt his *dictum*, that the bird to which the two above-mentioned bones belonged was a two-toed ostrich.

I now come to four bones of a large species of struthioid, collected by Mr. Theobald in the Western Punjab. These bones comprise two specimens of the first and second phalanges of the outermost digit¹ of a three-toed struthioid bird; one pair of these bones is somewhat larger than the other pair. I will not describe these bones on the present occasion, but will content myself with saying that as regards form, they agree almost precisely in form with the corresponding bones of *Dromæus novæ-hollandiæ*.

The dimensions of the four fossil bones and the two corresponding bones of *D. novæ-hollandiæ* are as follows, in inches:—

	Large fossil.	Small fossil.	<i>Dromæus novæ-hollandiæ</i> .
Length of first phalange	2·4	2·3	1·8
Antero-posterior diameter of superior surface of ditto	1·36	1·25	0·75
Transverse ditto	1·3	1·2	0·7
Antero-posterior ditto inferior ditto	0·9	0·7	0·46
Transverse ditto	1·0	0·8	0·6
Length of second phalange	1·5	1·3	0·8
Antero-posterior diameter of superior surface of ditto	1·1	0·95	0·55
Transverse ditto	1·3	1·1	0·62
Antero-posterior ditto inferior ditto	0·7	0·65	0·45
Transverse ditto	1·3	1·1	0·54

¹ Corresponding to the fourth of the typical series.

It will be seen from the foregoing measurements that the fossil and recent bones bear the same relative proportions, and that the larger fossils are almost exactly double the size of the recent bones. The difference in the size of the fossils does not appear to be greater than that which might occur in different individuals of the same species. There are some very slight minor differences between the fossil bones and those of *Dromæus novæ-hollandiæ*, but they do not appear to me to be more than of specific value; and I think that the fossils should undoubtedly be referred to that genus.

It may be well to observe, that the outermost digit of *Struthio* has its phalangeal bones of a much more slender type than those of *Dromæus*, and each bone is more nearly symmetrical in itself than in the latter genus. The stout and obliquely shaped fossil bones cannot therefore belong to *Struthio*.

Had it not been that M. Milne-Edwards had referred the struthious Siwalik bones in the British Museum to the two-toed genus *Struthio*, I should have not improbably referred all the bones to one species. The tibio-tarsus of *Struthio asiaticus* is, however, rather small for the fossil phalanges. For the three-toed Siwalik struthioid bird I propose the name of *Dromæus sivalensis*. If it should turn out eventually that M. Milne-Edwards was erroneous in referring the struthioid tibio-tarsus to the genus *Struthio*, and that that bone really belongs to a three-toed species, then it may possibly belong to *Dromæus sivalensis*. Irrespective of this question, however, the new fossil bones afford us indisputable evidence of the former existence in India of an emeu of double the size of the existing emeu of New Holland, and which must have rivalled in size some of the gigantic fossil three-toed wingless birds of New Zealand.

If we accept M. Milne-Edwards' *Struthio asiaticus*, it is clear that the ostriches of Africa and the emeus of Australia once had a common home on the plains of India, and it is possibly from this common home that they have gradually spread, till they are now isolated from one another on opposite sides of the globe.

The living faunas of India and of the Australian region are almost totally distinct; but there are a few indications in Celebes and some of the neighbouring islands of there having been a former communication between the African, Oriental, and Australian faunas; and it is probable that the same means of communication afford a passage for the *Struthionidæ*. Mr. Wallace,¹ in explanation of the supposed communication, suggests that a large tract of land formerly extended from Australia in a north-westerly direction to Asia, and that this old land was probably the home of the ancestors of *Sus*, *Babirusa*, *Phacochoerus*, *Anoa*, *Bubalus*, *Cynopithecus*, *Cynocephalus*, and *Mucacus*, to which we may now probably add *Dromæus* and *Struthio*.

Since the emeus and cassowaries are not found fossil in Australia or New Guinea, while numerous fossil species of marsupials occur throughout these islands, and since struthioids are known to have existed in the older pliocene (or

¹ Geographical distribution of Animals, Vol. I, p. 437.

upper miocene) in Asia, while the marsupials (with the exception of the *Didelphidæ*) have not been known out of Australasia since the Eocene period, it is not impossible that the struthioid birds are a much later introduction into Australasia than the marsupials. At page 340 of "Tropical Nature," Mr. Wallace says that Australia was isolated during the whole of the tertiary period, and on the next page that it has not improbably been isolated since the oolitic period. If I am right in referring the fossil Siwalik bird-bones to *Dromæus* (and they are certainly closely allied) we have indications of a much later connection between India and Australia.

NEW WADER.

The next fossil bird-bones I wish to notice are an associated sternum and an incomplete tibio-tarsus of a gigantic carinate bird, which probably belonged to the order Grallatores; though it presents certain peculiarities which appear to distinguish it from all other living birds. This sternum and tibia were in the collection of the Asiatic Society of Bengal, and were marked in Dr. Falconer's handwriting as having been obtained from the Siwaliks, though no locality is mentioned. The sternum has a bold convex carina, and has a considerable general resemblance to the sternum of *Argala* (*Leptoptilus*); the notch on either side of the xiphi-sternum is, however, much deeper and larger, and the xiphi-sternum itself larger and longer. The sternum is moreover more expanded laterally than in *Argala*. The peculiarity of this sternum, however, is that the distal half of the furculum, which alone remains, is completely anchylosed to the superior border of the sternum, so that no trace of division is visible. Behind this anchylosed furculum are the long coracoidal grooves, which are placed much more backwards than is usually the case in birds. I do not know of any instance among living birds of such complete anchylosis of the sternum and clavicles, such anchylosis being usually confined to the hypocleidium of the furculum and the manubrium sterni. The fossil sternum is of considerably larger size than that of *Argala indica*, but from its general form seems clearly to have belonged to a bird allied to that genus. The tibio-tarsus which was associated into the sternum lacks its distal extremity (astragalus), as well as some portion of its proximal extremity.

The fibula is anchylosed to the upper half of the tibia, which shows that the bones do not belong to a struthioid, in which the tibia and fibula are distinct. The bone has the general shape of the tibia of *Argala*, but is flatter superiorly, and, in place of being slender, is stout and strong like the tibia of the ostrich. The length of the imperfect tibia is about 14 inches, while its transverse diameter superiorly is 1·8 inches, and its antero-posterior diameter 1·2 inches.

As regards size, our tibia has a great resemblance to the gigantic *Gastornis parisiensis*¹ of the French eocene, which is only known by its femur and tibia, and which seems to have characters common to the Grallatores and Natatores. The tibia of *Gastornis*, however, expands inferiorly, whereas the Indian bone contracts: there is also a great hollow in the former on the anterior surface above

¹ Oiseaux fossiles de la France, Atlas, Vol. II, pl. 29.

the condyles, which does not occur in the latter. In *Gastornis* the tendon of the *tibialis anticus* muscle passes through a distinct bony arch, which I think does not exist in the Indian fossil. Again, the Indian tibia has the fibula anchylosed to it for half its length, which is not the case in *Gastornis*. I am not aware of any other living or fossil bird (except the *Ratidæ*), which has a tibia approaching in size to that of our fossil.

These two bones indicate the former existence of a carinate bird, probably allied to the adjutant, but which in stoutness and length of limb was intermediate in size between the ostrich and the emeu. I propose to call this bird *Megaloscelornis sivalensis*¹; the remains I hope to describe more fully on a subsequent occasion.

Argala falconeri, M.-Edwards.

The remains of *Argala falconeri* in the British Museum, according to M. Milne-Edwards (*loc. cit.*), consist of the proximal and distal extremities of a tarso-metatarsus, and two specimens of the distal extremity of the tibio-tarsus. Two of the bones indicate a bird larger than *Argala indica* (*Leptoptilus argala*), while the other two are of somewhat smaller size. In the Indian Museum we have three bones belonging to *Argala falconeri*, all of which were collected by Mr. Theobald in the Punjab: these bones comprise a very late cervical vertebra,² the distal extremity of a tibio-tarsus, and the first phalange of the outermost digit. The first two of these bones are of exactly the same size as the corresponding bones of *A. indica*, while the third is slightly smaller: as regards form all appear to me to be indistinguishable from the corresponding bones of the living species. Since some of M. Milne-Edwards' specimens are of somewhat larger size than the living adjutant, it is evident that the Siwalik adjutant attained a somewhat greater size than the living species; but as the bones of the two are indistinguishable in form, it appears to me to be very doubtful whether we have as yet any good evidence as to the specific distinctness of the living and fossil forms.

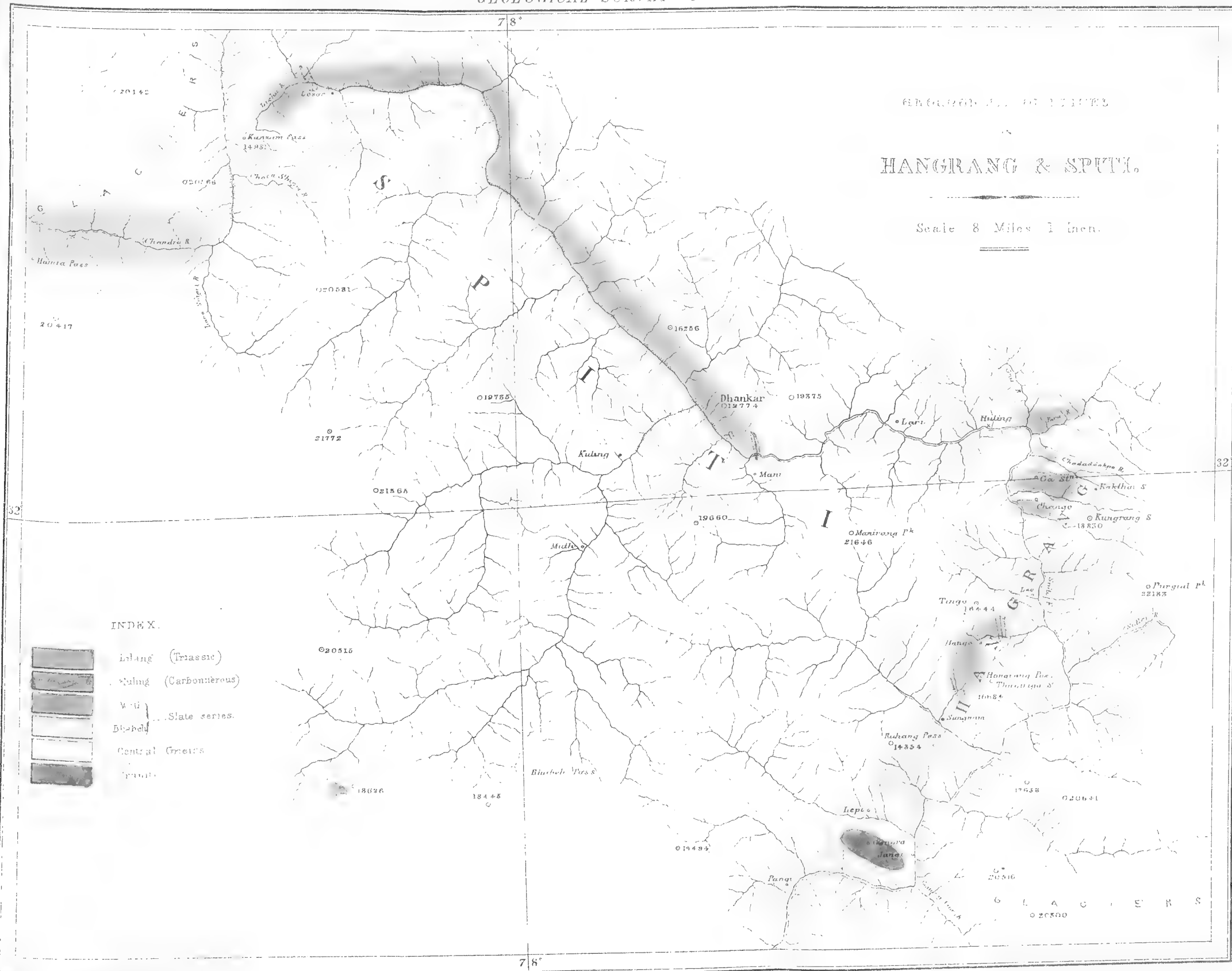
CONCLUSION.

Besides the above-described bones, there are in the Indian Museum a cervical vertebra and a tibio-tarsus of birds about the size of the common fowl, but whose affinities I have not yet determined.

There is also the distal extremity of the femur of a large unknown bird figured in the "Fauna Antiqua Sivalensis," as well as several fragments of bones of smaller birds. In the collection of the British Museum there is the distal extremity of the humerus of a large bird, which was recently discovered among some Siwalik specimens by Mr. Davis, who showed it to me; but I had then no opportunity of determining to what bird it belonged. It will be noticed that among these Siwalik bird-remains, those of *Argala falconeri* are the most common, and that the great majority of the known bones belonged to birds of large size.

¹ μέγας-αλος, σκέλος, ὄρνις.

² Rec. Geol. Surv. India, Vol. IX, p. 104.



This, I think, can only be accounted for by the larger bones being, firstly, more likely to escape destruction, and secondly, being more likely to be obtained by collectors. We are not therefore, from the paucity of small bird-bones, to argue that the smaller birds were not fully represented in the Siwalik fauna, any more than in the case of the small mammals, of which the remains are likewise extremely rare. Since birds, as a rule, are of far inferior size to mammals, it is only natural to expect that the discovered fossil bones of the former should only present a very small percentage of those of the latter.

With regard to the Siwalik tarso-metatarsus stated by M. Milne-Edwards to indicate a bird closely allied to the living Tropic birds (*Phaeton*), it seems incredible that a bird of that essentially oceanic genus could have lived in the land-locked Siwalik country. The difficulty may perhaps be got over by calling in question the authenticity of the locality of the bone, of which there seems no certain history.

NOTES OF A TOUR THROUGH HANGRANG AND SPITI, *by* COLONEL C. A. McMAHON.

Circumstances over which I had no control delayed my departure from Simla so long, that the time at my disposal was only sufficient to enable me to make road-side observations by the way. I could only devote one halt to explorations off the road.

In my last paper (*Rec. Geol. Surv.*, X, p. 204) I described the rocks of the Upper Sutlej as far as Jangi, and I now proceed to describe the section from that place to Spiti, *viâ* the Ruhang and Hangrang passes.

The dip of the schists and central gneiss between Pangi and Jangi varies from north-east to east-north-east. Between these places, as described in my last paper, frequent intrusions of granite culminate in an eruption on a grand scale; the granite constituting the core of the Gongra ridge, and extending in a north-westerly direction from near the confluence of the Todoong Gar river with the Sutlej, to Lepi. Whether it extends beyond Lepi I do not know. The rocks fringing this central granitic core, and forming the minor ridges of the Gongra range, are mica schists. On leaving Jangi (elevation 8,850 feet)¹ the dip is at first flat, but as Lepi (elevation 8,880 feet) is neared, a west-south-west dip is set up. Between Lepi and the top of the Ruhang pass (elevation 14,354 feet, T. S.) the dip varies from north-north-east to north-west. The rocks, which at first are silicious and micaceous schists, gradually get more and more slaty, and finally pass into unmitigated slates with a grey streak.

Whether there is a gradual transition from metamorphic crystalline rocks to clay slates—the one gradually passing into the other—or whether the transition is merely apparent, I cannot positively state. It would require, I think, a careful detailed survey of the ground to decide the question definitely. It is impos-

¹ The elevations given are generally those shown by my aneroid barometer: when the trigonometrical survey elevations are given, the letters T. S. are affixed.

sible for a Himalayan traveller, with a long and toilsome march before him, to crack *every* piece of rock he sees, and scrutinize it minutely; and when rocks on their weathered surface give no outward indication of a change, it would be quite possible, I imagine, to miss the border line between slaty micaceous or slaty silicious schists on the one side, and micaceous or silicious slates on the other. The difficulty is increased not only by the fact that some metamorphic rocks in this area closely resemble in external appearance the sandstones and slates of the palæozoic series in contact with them, but also from the circumstance that both series have been alike affected by comparatively recent disturbances.

I have no note of any granite veins, and I feel sure I did not see any in the schists at Lepi. I see no reason to suppose that the intrusion of the Gongra granite (which I believe to be albite granite) occurred at a later period than the albite granite of other sections; and I do not, therefore, think that the metamorphism of the schists at Lepi can be explained by referring it to the rise of the granite.

At the top of the Ruhang pass the dip changes to south-south-west, and the angle of dip is high all the way down to Sungnam (elevation 9,520 feet). The rocks resemble the slates and fine sandstones of the Simla slate series.

At Sungnam, the slates, which are here nearly perpendicular (dip extremely high to west-by-south), are of a light grey color; but on the way up the Hangrang pass they get darker in color, and become like the Simla slate beds that so much resemble some of the nummulitic clays. At an elevation of 10,150 feet, the northerly dip is recovered by a sharp and fractured anticlinal, along which some of the beds above, dipping north-east, seem to have been pushed over the beds on the south-west side of the anticlinal.

At an elevation of 11,050 feet, the slates terminate suddenly, their junction with the rocks above them being masked by a side stream, running down from the top of the Hangrang pass. On the other side of this stream, pink limestone appears, in beds of from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet in thickness. There are probably from 300 to 400 feet of them.

When first seen the pink limestones apparently dip north-north-west, but this rapidly subsides into a north-east-by-north dip. These beds are overlaid conformably by purple calcareous indurated clays that break under the hammer into lumps, and not into slaty slices. Over these is a small outcrop of a slate with a dark streak, which is overlaid, at an elevation of 12,000 feet, by a thin bed of dark-blue limestone. Then follow, in the ascending order, dark slates that break into acicular fragments. They reminded me so much of the argillaceous beds exposed on the eastern side of the Krol mountain¹ that it needed the test of acid to satisfy me that they were not calcareous. At an elevation of 12,300 feet these slates give place to dark-blue compact limestones, for the most part in beds of half a foot to two feet in thickness, and they continue up to the top of the pass (elevation 14,530 feet). A bed of greenstone occurs in them.

¹ Mem. G. S. I., Vol. III, pt. 2, p. 24.

Judging from the talus, I am under the impression that the rocks on the south-east side of the pass, namely, in the direction of the Thagiriga trigonometrical station, consist of slates faulted against the limestones; but I had no time to scale these cliffs to examine them. On the north-west side of the pass, and down to Hango (elevation 11,500 feet), the limestones continue; the north-easterly dip changes near the summit of the pass to a low west-north-west dip, producing, when the beds are viewed from below, an appearance of unconformity.

On the descent, at an elevation of 13,400 feet, clay slates re-appear, dipping south-west. From this point, owing to great contortion, the limestones and slates alternate several times, being sometimes perpendicular, at others dipping south-south-west. Near the bottom of the descent, a compact quartzite becomes prominent, sometimes perpendicular, sometimes dipping south-west-by-south. In color it varies from a bluish to a pinkish-white. Close to Hango, as another result of contortion, the thin-bedded limestones and slates re-appear, having an extremely high (nearly perpendicular) north-east dip.

The quartzites above described and the thin-bedded limestones at the top of the pass belong, I apprehend, to the Krol formation. I doubt if hand specimens could be distinguished from those taken from the Krol mountain itself. Most of the beds weather a dark blue, but some brown. The rock abounds in white calcite markings, similar to those so common in typical Krol rocks. The purple calcareous clays I have described as occurring on the south side of the pass reminded me of the purplish-red, sometimes calcareous clays of the Krol and Boj.

Proceeding onwards towards Leo on the Spiti river, the first rock seen on leaving Hango, and which dips north-east, is a highly silicious white limestone (weathering white) with a faint shade of green in it, due apparently to the presence of a little chlorite. On the weathered surface I saw what looked like a cast of *Nautilus spitiensis*, only about half the size of that figured in Plate IV, Memoirs vol. V, as one of the Lilang fossils. It seemed to vanish into nothing when examined with the aid of a lens, and broke into pieces on the first application of the hammer, leaving me in a painful state of doubt whether I had seen a real fossil or not.

The limestone just described is overlaid by a hard silicious dull pinkish-white limestone that weathers a dull red-brown. It might easily be taken for a quartzite, but it effervesces slightly with acid (strongly when powdered), and a qualitative analysis of it shows that it contains a good deal of lime and some magnesia. A thin slate is intercalated with these limestones. There are some hundreds of feet of these rocks, but I cannot say exactly how thick they are, as the hill side is obscured by talus for some miles. The reddish-weathering limestone appeared, from blocks that had fallen down, to be overlaid by a bluish-white quartzite.

As I journeyed onwards the north-east dip appeared to flatten and then to change temporarily to east-south-east, the change of dip bringing down to the road dark-blue limestones resembling those at the top of the Hangrang pass.

The white limestones at Hango are, I apprehend, the same rocks as the pink limestones on the south side of the pass.

Further on, at a point where the road, having rounded a spur, winds into the mountain side, slates re-appeared dipping west. As the silicious limestones did not crop out between the blue limestones and the slates, I presume they were hidden by the talus, which, at the level of the road, is very abundant along this section. As the crystalline series was neared I came to a pale bluish-white slate weathering a bright yellowish ochre color in irregular patches. Associated with the latter was a thin bed of dark slate, in some places as black as coal.

From these rocks I passed by a sudden transition to the crystalline series. The change takes place just where the road from Hango rounds the edge of the Tinga ridge, at an elevation of 11,500 feet, before the commencement of the descent to Leo. The slates rest upon the crystalline rocks, and no material change of dip would be observed in passing from the one series to the other.

The crystalline series extends from the point indicated up to (and probably beyond) the Para river, but at and beyond Chango, as will be shown further on, they are overlapped by pink limestones and calcareous slates. The lowest beds in the crystalline series at Leo are massive quartzites; these are followed by thin-bedded white and bluish-white quartzites, with some beds of mica schists. Higher up in the series the mica schists become more prominent. Some of the latter are fine-grained silicious rocks, showing no mica on the weathered surface.

The crystalline rocks, quite up to their junction with the unaltered rocks, are riddled through and through by dykes and veins of albite granite, varying in thickness from about 30 feet to the fraction of an inch. The granite is undoubtedly intrusive. It may be seen throughout the crystalline series between Leo and Chango, from the bed of the Spiti river up to the tops of the highest peaks, profusely penetrating the strata in all directions; sometimes darting across them in long zigzags, like forked lightning; at others, following the line of bedding for some distance, and then either dwindling away into thin strings, or terminating suddenly to burst out in adjacent strata with redoubled force.

The granite in the gneiss in the vicinity of Chango has already been identified as albite granite (*Memoirs*, vol. V, p. 154). It presents all the characteristics of the intrusive albite granite of the Wangtu section of the Sutlej valley, being a mixture of quartz, muscovite, schorl, and a snow-white felspar (*occasionally* showing triclinic striations) that scarcely weathers at all. When the schorl is sparsely scattered through the rock, the muscovite is plentiful and in good sized packets or leaves, but when the black tourmaline is abundant, the muscovite becomes very subordinate and dwindles to thin flakes of small size. In some places the schorl is profusely scattered through the rock, in irregularly shaped fragments.

Near Chango I found cyanite in mica schists. It was of beautiful cobalt blue, shading into a pearly white, but the blades were not nearly so large as those of the mineral found in the central gneiss near Wangtu. In the same locality there were some chiasolite schists near granite.

I first met with gneiss within a few miles of Chango. It showed again between the latter place and the Para river, and on the banks of that stream. Dr. Stoliczka identified the gneiss on the left bank of the Para river as the *central gneiss* (Memoirs, vol. V, p. 16), and though I saw none porphyritic in structure, I do not doubt the correctness of the identification. That the crystalline rocks I have described belong to the central gneiss series may, I think, be accepted on the evidence of their crystalline structure, and the presence in them of cyanite and intrusive albite granite, characteristic features of the typical Wangtu section. The dip of the crystalline rocks at Leo is west-by-north, but this changes gradually to west-south-west, and finally at Chango to south-west.

About two miles south of Chango a ridge of limestone rocks, the dip of which varies from south-west-by-south to south, runs up from the Spiti river and abuts on the crystalline series just where the road from Leo to Chango crosses the ridge. At this point the dip is south-west-by-south. The limestones consist of thin-bedded, pale blue and cream-colored beds, weathering from a pale pink to a yellow ochre color, intercalated with dark blue calcareous slates. The latter effervesced freely with acid wherever I tested them, but they break up into small thin slices, and look more like slates than limestones.

In a cliff overhanging the Spiti river, I found what appeared to be coralline remains in the pale blue limestone; but they were in bad preservation and have not been identified.

In the bed of a stream to the east of Chango and between the latter village and the ridge above described, and also at the village of Chango itself, some hard dark slates are exposed. Dr. Stoliczka also mentions (Memoirs, vol. V, p. 19) the occurrence of silurian slates opposite Shalkar. The slates dip under the limestones.

On the north side of Chango the limestones distinctly overlap upon the crystalline series. To the north-east of the village, where two irrigation channels "take off," as engineers say, from the stream flowing down from between the Kakthai and Kunrang trigonometrical stations to the Spiti river, the crystalline series is to be seen in contact with the pink limestones and dark calcareous slates. The mica schists are riddled with albite granite veins up to the point of contact.

The limestones overlap the schists; and though the plane of contact dips at a high angle, the junction of the two series of rocks is evidently not a faulted one, for about a mile lower down the stream, the crystalline series again crops up and forms a cliff overhanging the river; the identity of these rocks here with those higher up the stream being established by the presence of two albite granite veins in the cliff alluded to. Further evidence of the fact that the limestones overlap the crystalline series was obtained as I journeyed onwards along the line of strike.

From Chango (elevation 10,150 feet) up to the top of the Chandan Namo ghat¹ (elevation 12,340 feet), the rocks consist of similar limestones to those

¹ Marked Ga station on the map. It is opposite Shalkar.

described as occurring in the ridge south of Chango; in both ridges white and grey quartzites occur in connection with them; but the whole hill-side is covered with talus, and only little outcrops of rocks *in situ* are seen here and there. The pink limestones at the commencement of the ascent dip north-north-east and north-by-east, but the dark calcareous slates are generally vertical or dip about in all directions. At the bridge over the Chadaddokpo the crystallines (mica schists and gneiss well riddled with albite granite as usual) re-appear in force on both banks of the stream. They appeared to extend a considerable way down the stream. Dip here north-west-by-west. On rising from the bed of the river I came again to unaltered whitish blue limestones, whilst beyond, in the same line of strike, the mica schists and granite re-appeared. In the bed of the Para river the gneiss is so riddled with granite that its metamorphic character is nearly obliterated.

Proceeding westwards from the camping ground on the banks of the Para river (elevation 10,580 feet) the rocks are at first white quartzites dipping east-by-south; then follow compact blue slaty limestones, and then a pale salmon pink limestone weathering a light ochre brown. The blue beds break up into thin slaty slices, and the whole, no doubt, are a continuation of the beds seen at Chango. They continue over the ridge down to the Ghu river. As the stream is neared the white quartzite seen on the banks of the Para re-appears, dipping east-north-east and north-east-by-east. It weathers a reddish-brown. Below it are grey quartzites, and below the latter, in the bed of the stream, is a pale whitish-grey slate sufficiently soft for a knife to cut well into it.

The pink limestones and calcareous slates in contact with the crystalline series at Chango are, I apprehend, identical with the pink limestones and slates seen at Hango; but I feel some difficulty at present in giving a name to them. They are above the silurian slates (overlapping them and resting on the crystallines at Chango), and are overlaid by the dark Lilang limestones at the Hangrang pass and Hango. They appear to occur again, as will be mentioned further on, in the same order, between Losai and the Kanzam pass. I think they answer best to the Muth middle beds, which Dr. Stoliczka correlated with the Blaini limestone of the Simla area (Memoirs, vol. V, p. 141), and in coloring the accompanying map, I have provisionally classed them as Muth middle beds. Very often both the weathered and fractured surfaces of the pale blue and pink limestones reminded me of the Blaini limestone of the Simla area.

I considered it right to note (page 59) that I saw at Hango what had the resemblance of a triassic fossil, but unless and until other triassic fossils are found in the pink limestone beds, I do not think it would be safe to attach importance to the circumstance.

Proceeding onwards towards Huling, the road leads over what appears to be a continuation of the same series for a short distance, when these rocks are suddenly cut off, apparently by a fault with no great throw; the road, which follows the line of strike, passing suddenly from white quartzites to silky slates containing some beds of very pale blue limestones (both weathering reddish-

brown), being the beds of the Bhabeh series described by Dr. Stoliczka at p. 19, vol. V, *Memoirs*.

These rocks at first dip north-west, but eventually round to west-by-north; the change being marked by a great contortion amongst the upper rocks on the left bank of the Spiti. The silky slates are succeeded by rocks higher in the series; those described at p. 20 of Dr. Stoliczka's *Memoir*, viz., beds of light colored quartzites and quartzite sandstones intercalated with dark slates that splinter into small thin slices. The debris of these slates imparts a very dark tint to the mountain sides, especially when seen from a distance, but whenever I tested them I found that they had a pale grey streak.

These beds on the Spiti river, between Huling and Po, have the same coloring in the accompanying map as the slates south of Leo and of the Kanzam pass; but in both of these latter regions they more closely resemble the slate series of the Simla area; and I was unable to decide from the cursory survey of the rocks along the route I followed, whether the difference in the character of the beds is due to alteration in their lateral extension, or whether they occupy a different horizon in the palæozoic series. From Dr. Stoliczka's remarks at page 21 of his *Memoir*, he would appear to have held the former view, and I think it is probably the right one, but the point can only be satisfactorily determined by the survey of a wider area than I had an opportunity of visiting.

Near Lari the strata become vertical for a short distance, and here I observed a thick bed of the contemporary greenstone described by Dr. Stoliczka as occurring in the palæozoic formation of Spiti (*Memoirs*, vol. V, p. 20). For some distance beyond Lari, angular blocks of this rock on the road side attested its presence in the cliffs above, but if it again dip down to the level of the roads, the outcrop must be buried under talus, as I did not see the rock *in situ* again.

From Lari onwards I did not observe any material change in the character of the rocks until nearing the point where the river Spiti takes a sudden north-west turn near Mani.¹ Here the strata suddenly dipping down to the river and rising on the opposite side form a sharp synclinal, along the axis of which the Spiti river runs for many miles. To the south-east the synclinal can be seen dying out among the peaks overhanging the Manirang pass, whilst to the north-west it may be traced for about ten miles beyond Dhankar, the bottom of it rising higher and higher and fading away in the mountains on the right bank of the Spiti.

This sharp bend in the strata brings down the upper rocks, and amongst them I observed a conglomerate, in a cliff overhanging the road on the left bank. There is about 40 feet of it. The matrix is a brown slaty rock; and it contains numerous pebbles of white, grey and reddish quartzite of irregular, rounded and subangular shapes. The largest I saw was about 4 inches in diameter.

This rock resembles the Blaini conglomerate of the Simla area. On the conglomerate rests a limestone containing numerous fossils, but in such bad preservation that none have been clearly identified. This was followed in the ascending

¹ Mani is on the right bank below Dhankar.

order by a brown sandstone which doubtless belongs to Dr. Stoliczka's carboniferous series. Then came talus, then slates followed by limestones interbedded with slates, and finally massive blue compact limestone (Lilang), weathering blue and brown in irregular patches.

The Lilang limestones which are exposed from this point almost the whole way up the valley are very like typical Krol rock. In color, in the thickness of their beds, and in often containing tortuous white calcite markings, they much resemble the rocks of that series. As I have described, the Lilang limestones of the Spiti valley, and the dark limestone seen at the top of the Hangrang pass, as both resembling typical Krol rocks, I need perhaps hardly add that they also closely resemble each other. In the absence of fossil evidence to the contrary, I conclude that the upper Hangrang beds belong to the Lilang series.

I may mention in passing, that I saw the conglomerate again a few miles beyond Dankar, on the left bank of the Spiti, a few feet only above the bed of the stream. A considerable thickness of a light colored calcareous sandstone containing pebbles similar to those in the conglomerate opposite Mani is overlaid by a brown slaty rock, also containing similar pebbles. This conglomeratic sandstone is composed of grains of unequal size cemented together with carbonate of lime and earthy matter exhibiting rusty reddish spots on the fractured surface. It appears to have been squeezed up from below the strata at the point indicated, having been subjected to great strain and contortion.

The section from Dankar up the Spiti is described at pp. 26, 33 of Dr. Stoliczka's Memoir, and it appears from the remarks at p. 33 that between Losar and the Kunzam pass, the section is a repetition of that described by Dr. Stoliczka between Mnth and Kuling. At the point where the road turns up the Lichu valley between Losar and the Kanzam pass, I observed a thick bed of pink limestone; but as a storm of two and half days' duration had covered the whole country with snow, and inflicted on me a sharp attack of snow-blindness, I was unable to explore this locality in detail.

The slates re-appeared near the Kanzam pass. From the top of the pass (elevation 14,931 feet, T. S.), down to Kátza, a halting place where the Chota Shigri river joins the Chandra, they resemble typical Simla slates. Dip north-east-by-north. On the left bank at Kátza the dip suddenly changes to very high south-south-west, and the slates are more silicious, and some of them have a micaceous glaze previously absent. The central gneiss appears with the Bara Shigri river, and huge blocks of it form a prominent feature in the moraine of the Shigri glacier. As I was making forced marches over heavy snow, I could not linger to explore this interesting neighbourhood, but Dr. Stoliczka states (p. 15 of Memoir) that "the boundary of the gneiss and of the *overlying*¹ silurian rocks" may be seen on a stream north of the Shigri glacier, six miles in a straight line south of the Kanzam pass. The Chota Shigri is probably the stream indicated.

¹ See also p. 17 and p. 311 of Vol. V.

The Shigri moraine passed, the talus of the mountains on the left bank of the Chandra consists of nothing but blocks of central gneiss, and finally that rock itself crops out *in situ* on the road side.

The absence of blocks of foreign rocks, I notice in passing, is hardly favourable to the view that the glaciers of the upper Chandra became confluent and flowed down the valley in recent geological times.

The central gneiss of the Chandra valley is often granitoid, and is penetrated by the albite granite (Memoirs, vol. V, p. 170). It extends to near the top of the Hampta pass (elevation 14,000 feet), where mica schists show under it, dipping north-west. Descending into the Kulu valley the gneiss shows for a considerable way, when it is succeeded by mica schists. The dip flat on the top of the pass, gradually veers round to west, and this again brings down the gneiss. The dip, which is usually low, wavers about sometimes in one direction and sometimes in another, being south-east at Jagatsukh and north-east at Dwára.

The continuance of the central gneiss in the micaceous and silicious schist beds, up to a mile north of Naggar, is attested by the presence of angular blocks on the road side that have tumbled down from cliffs above. From this point to Bajaura the metamorphic rocks consist principally of a dull brown mica schist, that smells earthy on the fractured surface, and generally does not show any indication of mica on its weathered surface.

The section between Sultanpur and Narkanda has been described by Mr. Medlicott (Memoirs, vol. III, p. 57), but I may briefly note, to complete this sketch, that the Sutlej valley limestones suddenly crop up about a mile south of Bajaura, and abruptly disappear about two and half miles north of Manglaur, where schists similar to those described as occurring between Naggar and Bajaura re-appear. The gneiss shows in force several times between Kot and Dulash, and frequently from thence down to the bed of the Sutlej. On the Kotgarh side, the dip coinciding with the slope, it is the only rock seen for 1,900 feet of vertical height above the river. From this point to within a few miles of Mattiana the rocks consist of schists similar to those south of Naggar in the Kulu valley.

The "graphitic schists" on the north side of the Jalori pass¹ are very similar to rocks seen round Kotgarh, and between the latter place and the Nogli river south of Rámpur. These rocks puzzle me very much. They are dark carbonaceous schists or slates with a micaceous glaze on them, and by their disintegration make coal-black earth. They are associated with limestone which occurs in more than one place on the north side of the Jalori pass, and a band of which crops up in several places under Kotgarh and along the Sutlej valley up to the Nogli river. Are these Infra-Krol rocks, lying closely on the crystalline series, or do they belong to the latter? The former would appear to me probable.

But without drawing any inference from these doubtful rocks, my observations during the present and previous tours show that, on the north as on the south of the central gneiss, the upper calcareous groups of the great palæozoic series originally overlapped the slaty series and rested on the crystallines.

¹ Mem. G. S. I., Vol. III, pt. 2, p. 57.

GLACIATION.

On the top of Chandan Námo pass (close to the Ga station, above Chango), I observed a considerable number of rounded river boulders of red quartzite and other rocks that do not occur locally. The red quartzite was probably derived from the Muth beds in Spiti. Beyond and at a lower level, I occasionally met with rounded boulders of trap, doubtless from the palæozoic formation of that valley (Memoirs, vol. V, p. 20), whilst 670 feet above the Para river, I observed numerous horizontal beds of river conglomerate. The boulders on the top of the Chandan Námo pass were undoubtedly rounded in the bed of a river by the action of the water, and there are no grounds for supposing that they were ice borne. The only explanation that appears reasonable to me is that the bed of the Spiti river was formerly as high as the top of the Chandan Námo pass, which is about 2,400 feet¹ above the present bed of the Spiti river.

Dr. Croll, in chapter XX of his *Climate and Time*, and Professor Geikie in chapter XXV of *Jukes's and Geikie's Manual of Geology* (3rd edition, 1872), discuss the rate of the erosion of rock surfaces evidenced by the amount of sediment annually carried down by the river systems; and the rate of erosion at which seven rivers specified remove one foot of rock from the general surface of their basins is said to vary from 6,346 years in the case of the Danube, and 6,000 years in the case of the Mississippi, to 929 years in the case of the Po. The rate given for the Ganges is one foot in 2,358 years.

Professor Geikie takes "the proportion between the extent of the plains and table lands of a country and the area of its valleys to be as nine to one," and assumes "that the erosion of the surface is nine times greater over the latter than over the former area." If, adopting this principle, we assume that within the mountain valleys of the Gangetic basin the erosion is nine times more rapid than over the rest of the basin, this would make the rate of erosion over the mountain area one foot in 262 years.

But the agents of denudation are much more powerful within the river basin of the Ganges than within that of the Sutlej. The watershed of the Ganges embraces a large area of exceptionally heavy rainfall, rising as high as 524 inches per annum in the Khasi hills, being "the greatest rainfall in the world," (Huxley's *Physiography*, p. 48); and within this area the agents of denudation must operate with exceptional activity. The rainfall over the watershed of the Sutlej, on the other hand, is comparatively light, being probably greatest at Simla, where the average for 15 years, from 1862-63 to 1876-77, was 75.1 inches. As you proceed higher up the Sutlej, the fall decreases, and beyond Wangtu becomes extremely light.

¹ Measured by my aneroid barometer, the elevation of the Spiti river at Leo is 9,550 feet, and at the confluence of the Ghu river 10,125 feet, the distance between the two points, measured straight across the map, being 13 miles. The top of the pass measured by my barometer is 12,340 feet. The weather being fine and cloudless, there could have been little variation from climatic causes.

Mr. J. B. Lyall, in his settlement report of the Kángra district (1874), states (page 164) that "light showers of rain occur" in Spiti, "in July and August; and in winter, snow falls only to the depth of $2\frac{1}{2}$ feet." As "10 inches of snow roughly represents 1 inch of rain" (Huxley's *Physiography*, p. 63), $2\frac{1}{2}$ feet of snow is equivalent to a rainfall of 3 inches. Even on the assumption that the fall of snow on the high peaks and passes is greater than that mentioned by Mr Lyall, the average for the whole of the Spiti valley cannot be in excess of 10 inches in the year, and the bulk of this falls as snow.

No hot winds penetrate to these elevated and mountain-locked regions to cause sudden thaws; the clear frosty air is usually without a cloud, and the snow "melts gently" (Lyall, p. 162).

That denudation proceeds slowly in the region under consideration will, I think, be evident when we consider that though the Spiti (a tributary of the Sutlej) flows over comparatively soft limestones and friable slates, whilst the Sutlej at Wangtu has to cut its way for miles through intensely hard granitic gneiss, yet the bed of the Spiti opposite Shalkar is still 4,724 feet above the Sutlej at Wangtu,¹ the distance between the two points being only 45 miles as the crow flies.

The deepening of the bed of the Satlej at Wangtu must be a very slow process; but clearly the excavation of the Spiti valley is a still slower operation.

The fall of the Sutlej at Wangtu is about 50 feet per mile.

I think, with reference to the only data we have to enable us to form a rough idea on the subject, that the rate of the deepening of the bed of the Spiti at the point under consideration is probably not more rapid than 1 foot in 400 years. At this rate it would require 960,000, or in round numbers say about one million of years,² for the excavation of the Spiti valley between Shalkar and the Ga station.

At the rate of 1 foot in 400 years, the total depth excavated in 80,000 years would be 200 feet only; so that if the last glacial epoch terminated as recently as 80,000 years ago, the date fixed by Dr. Croll on astronomical data (pp. 325-327, *Climate and Time*), the Upper Sutlej and Spiti rivers, and the agents of denudation operating on the slopes of their watersheds, cannot have effaced the broader marks of the work done by glaciers during that period. If then any *great* increase of glaciation during the last glacial epoch took place in the region under consideration, we ought to find decided traces of ice sculpture in our Himalayan upland slopes and valleys.

A similar conclusion appears to have been arrived at by experienced geologists regarding England. "Post-glacial denudation generally," states Mr. Good-

¹ The Sutlej at Wangtu, 116 miles beyond Simla, is 5,200 feet above the sea.

² This is less than half the rate adopted by Geikie for his average valley. "For we find by a simple piece of arithmetic, that at the rate of denudation which we have just postulated as probably a fair average, a valley 1,000 feet deep may be excavated in 1,200,000 years, a period which, in the eyes of most geologists, will seem short enough." Juke's and Geikie's *Manual*, p. 431.

child (*Q. J. G. S.*, vol. XXXI, p. 99) "has affected so little, that by far the greater part of the present surface-configuration has in one way or another resulted from the former presence of the great ice sheet."

Bearing this principle in mind, I looked around me, during my recent tour, for the evidences of former glaciation. I do not know whether any one has ever supposed that the Himalayas were covered during the last glacial period with an ice cap, but I may note that whilst I saw nothing to favor such an idea, I saw much to negative it. The contour of the hills and valleys in those parts of the interior of the Himalayas that I have visited is sharp and angular, and where rounded outlines are seen, they are sufficiently explained by the action of sub-aërial forces on comparatively soft and friable rocks.

But setting aside the idea of an ice cap, the question remains—was there formerly any great extension of local glaciers, and if so, within what limits? To this question I answer that, whilst I saw evidence of the former extension of existing glaciers, I saw nothing during my tour to lead me to believe that these glaciers had ever, within a reasonable geological period, extended lower than 11,000 or 12,000 feet above the sea.

On looking down from a high vantage ground, deep narrow side valleys may be seen on the Upper Sutlej, below that level, in which the course of the streams flowing through them is so sinuous that the sharp headlands formed by their sudden bends interlace like the nuts of cogwheels working into each other. The flow of ice in a glacier being analogous to the flow of water in a river and its tributaries, a grand glacier filling the valley of the Sutlej would not have prevented the flow of ice from the side glaciers into the main glacial stream. But had these side valleys ever been filled with glaciers, the sharp interlacing headlands would have been gradually worn down to smooth surfaces, and the valleys straightened and widened.

The only valley in the Himalayas I have yet seen that is shaped like a glacier valley is the Spiti valley. The greater part of it is more than 11,000 feet above the sea, and its bottom, especially in the upper half of the valley, is broad and flat, whilst the bounding mountain sides rise abruptly in a wall-like manner at a high angle, and send no sharp projecting spurs into the valley. But if, as I think highly probable, the upper portion of the valley owes its shape, in part at least, to the action of ice, the period during which a glacier flowed down the straight course of the Spiti river must have been very remote; for I noticed about half the way up the valley a side valley partaking of the character of those described above; whilst the flat boulder bed which, in the upper valley, rises high above the river, seems to owe its origin in part to the action of the river, and in part to talus shot down from the bounding cliffs. It is not of glacial origin.

I now proceed to note the evidence which I obtained of the former extension of glaciers. At the head of the Spiti valley the Lichu river flows down from the peaks that surround the Kunzam pass, into the Spiti. There is probably a glacier up the side valley crowned by the snowy peak 20,581 feet high, but there is now no

glacier in the Lichu valley between the Spiti and the Kunzam pass. About four miles in a straight line from the top of the Kunzam, a spur from the Shilatakar peak runs down to the Lichu river, and an ancient glacier in its course down the valley must have ridden over it. The rocks there, at an elevation of 14,000 feet, are thinly laminated slates, the dip of which is perpendicular, and the strike of which points across the valley at right angles to what must have been the course of the ancient glacier. The slates generally break up on the surface in thin flaky slices, but here and there long patches of the rock are *moutonnée*, polished and striated. The polishing is even now sufficiently perfect to obliterate all traces of the lamination of the slates. The striæ are well marked; they are generally in a direction of the axis of the valley, though they often cross each other at inconsiderable angles. As evidence of former ice-action nothing would be more complete and perfect. The splinting friable slate on which this ice-action is recorded is the last sort of rock on which I should have expected to find it.

Regarding the recession of glaciers, I note that the Big Shigri, as evidenced by its terminal moraine, has shrunk somewhat; but in the case of the Pirad glacier, the next to the west of the Bara Shigri, the shrinking is very evident. The road passes within about quarter of a mile of this glacier, and from either side of it a large lateral moraine may be seen curving down the valley until it reaches the river, three-quarters of a mile, or a mile, from the present end of the glacier.

Again, the head of the valley, up which the road to the Hamta pass lies, is filled by a glacier that extends a little below the entrance to the pass. The old terminal moraine of this glacier may now be seen about one and a half miles lower down the valley, rising in steep banks some 50 or 60 feet above the talus, shot down from the sides of the valley.

About a quarter of a mile below the Pirad glacier, on the side of one of the moraines, there is a huge block of the central gneiss, well rounded, polished and striated on all sides but one.¹ The impression I derived from examining it was that it must have originally been a boss of rock projecting from the side or bottom of the glacier bed, and that it was ultimately torn away from its parent rock and deposited where it now rests. I did not measure the block, but it cannot be smaller than 50' \times 50' \times 50'. One side has been ruptured from the block, apparently by the action of frost on water filling a crack, and its pieces rest by its side.

¹ Exclusive of the side on which it rests, which, of course, cannot be seen.

NOTE ON A RECENT MUD ERUPTION IN RÁMRI ISLAND (ARAKÁN) BY F. R. MALLET,
F.G.S., *Geological Survey of India.*

In the account of the mud volcanoes of Rámri and Cheduba given in Volume XI, part 2, it is mentioned that there is a notion prevalent amongst the islanders that eruptions take place more frequently during the rains than at other times of the year. The few dates of eruption on record, in as far as they go, do not bear out this idea, but the number is too small to generalise upon.

Were the idea of an increase in activity during certain months of the year confined to the unsophisticated inhabitants of these islands, the point might perhaps be scarcely worth examination. A greater tendency to eruption at certain periods has, however, been suspected to exist in some other parts of the world. It is stated by Dr. Horsfield, that eruptions from the mud volcanoes of Java are more violent during the rainy season than at other times, and M. Dubois de Montpéreux mentions that out of six eruptions from the mud volcanoes near the entrance to the Sea of Azov, five occurred between February and the 10th of May, the only known autumnal eruption having been on the 5th September.¹ Whether, therefore, the belief of the Arakán islanders be well founded or not, the point is worth investigation.

In this connection the following letters, which have been placed at the disposal of the Geological Survey by the Commissioner of Arakán, are valuable as the first contribution towards a catalogue of eruptions sufficiently extended for generalisation. It is hoped that we may be able to make such in time through similar communications from the Officials of the Rámri district, and others who may take an interest in the subject.²

From CAPTAIN J. BUTLER, Deputy Commissioner, Kyouk Phyou, to the Commissioner of Arakán, Akyáb,—No. 35-12, dated the 16th July 1878.

In compliance with the instructions conveyed in your letter No. 732-165, General Department, dated 22nd ultimo, I have the honor to state that the following individuals were

¹ Records, G. S. I., Vol. XI, p. 201.

² It will be seen by reference to the paper quoted above, that there are some other points, also, connected with the eruptions, concerning which our information is not sufficiently detailed. The following list of questions may perhaps be useful as a guide in obtaining information from the villagers:—

1. Informant's name and village.
2. Locality at which the eruption took place. Name of village, with distance and bearings from one or two well-known places.
3. Date of eruption, and time of day at which it commenced.
4. Was it preceded or accompanied by any perceptible earthquake?
5. How long did the eruption last? Did it begin suddenly, or increase gradually in violence, and did it end suddenly or gradually?
6. Were there any flames during the eruption? If so, how high did they rise above the top of the hill, when largest, and how long did they last? Was the flame continuous or intermittent?
7. What is the shape of the hill, and its height? Was it formed entirely during the recent eruption, or was part of it there previously? Is it conical, and is there a basin or hollow (crater) at the top? If so, what is the diameter of the hollow, and does it contain mud?

examined by the Kin Thoogyee, relative to the volcanic eruption which took place in his circle a few months ago, viz. :—

- 1. Kulla-kyee of Kon-boung Tau Village,
- 2. Ya-ba Hkyoung of Peu-lay-na ditto,
- 3. Pau Hla Oo of ditto ditto,
- 4. Tha Htoon Hpyoo ditto ditto,
- 5. Tha Htoon Oung ditto ditto,
- 6. Ya-ba Oung of Ioung Hkyooein ditto,

and from their collective evidence the Thoogyee has communicated the following :—

1. The eruption occurred near the village of Peu-lay-na, a spot bearing about 460 yards north of the above village, 1,000 yards west of the Yua Ma village, and $\frac{1}{4}$ of a mile east of the sea-shore.

2. It occurred on the 19th of March 1878, at 7 o'clock in the morning.

3. No earthquake occurred, the earth merely cracked, and from the fissure a hill began gradually to rise.

4. The eruption lasted 11 days, and began increasing gradually day after day, ending in the same manner. This was ascertained by means of a post which was put into the earth for the purpose of watching the height of the hillock as it increased. A few days, however, before the eruption ceased, the post was found lying some 14 or 15 cubits distant from the place where it had been put in.

5. No flames occurred at the time of the eruption : a lad, however, who happened to be close to the spot, accidentally dropped into the crater a box of matches, when immediately a large flame to the height of about 25 cubits above the top of the hill issued forth, and which continued burning for two days and a night before it went out.

6. The shape of the hill is said to resemble an inverted boat, and its height is 18 cubits. There was previously in the same spot a small hill about 9 feet high, and on this hill the eruption took place. The hill is flat on the top, cracked in several places, and the cracks filled with mud.

7. The lava or stuff thrown up was mud mixed with stones, and the mud thin and watery ; when first thrown out the mud was warm. Inside the cracks it is very hot when felt by the hand. The stones were small in size, and were not thrown up much higher than the summit of the hill.

8. There is another hill of the same kind as this one in the neighbourhood which was formed over a hundred years ago.

8. Was the stuff thrown up mud only, or mud mixed with stones? Was the mud thin and watery, or thick? Was it cold, warm, hot or very hot when first thrown out? How large were the biggest stones thrown out, and how high were they thrown?

9. Are there any other hills of the same kind in the neighbourhood, and if so, have any of them been formed during the remembrance of the present generation; if so, how many and when?

Any further information will also be acceptable.

¹ Specimens sent to the Geological Museum were light grey mud and pieces of grey shale. A few pieces were reddish, doubtless from having been exposed to the heat of the flames.—*Vide* Vol. XI, pp. 196, 201, 202.

9. The Burmese, as a rule, are very superstitious in matters of this sort, and generally ascribe such a phenomena to the work of a dragon (Nagah).

From CAPTAIN GEORGE ALEXANDER, Officiating Deputy Commissioner, Kyouk Phyoo, to the Commissioner of Arakán Division, Akyáb,—No. 3, dated Camp Rámri, 11th December 1878.

I have the honor to submit a further report on the subject of the volcanic eruption near Moo-yin in the island of Rámri, and in continuation of my letter No. 35-12 of 1878.

The mound first made its appearance on the night of the 18th March 1878; at least the first people who saw it were some women, who went out to cut wood before dawn on the morning of the 19th, and came across a mound gradually rising from the earth, and being frightened, believing that it was a "Nagah Doung", or hill raised by a dragon, they ran away. They saw no fire, nor did they perceive any earthquake. They state that the mound continued rising for 12 days, and that it was on fire for a day and a night. Lah Bah Chyoung, the writer of the circle Thoogyee, who visited the spot at about noon on the day in question, says he found smoke and fire issuing from cracks in the mound when he arrived, but states that the surface of the ground was smooth and hard; that the earth was being forced out of an area of about three bamboos or 36 feet in length, and gradually made its way westward towards the sea. It appears to be doubtful whether the mound itself vomited fire, or whether it was set on fire by a small child with a cheroot; at any rate it was on fire on the day after its appearance, and the flame burnt for two days, not steadily and regularly, but spurning up into the air by fits and starts, for some 20 or 30 cubits; there was a strong smell of earth-oil whilst the mound was on fire, and it is described as having been so powerful and pungent as to make the women near giddy; there appears to have been no active sudden eruption, merely an upheaving of the earth gradually. And the villagers state that sticks planted 6 inches or a foot in the ground in the evening would be found to have been carried considerably westward by morning, the first night 14 cubits; but the distance kept decreasing inversely as the days went by. This information is gathered from the women who first saw the mound and from other residents close by.

Directly inland, and at a distance of some 300 or 400 yards from the present upheaval, is a conical hill which has the appearance of being one of volcanic origin. The present elders of the village state that in the year 1146 (Burmese era), or 94 years ago, a volcano appeared which threw out large quantities of stones and residue, and gradually formed a hill which some 65 years ago was about 23 feet high, and which is now estimated at about 40 feet high, although it is difficult to say where the hill begins, and the top is considerably more than this height above the surrounding paddy cultivation. This mound is called by the Arakanese "Nagah Bwai" or dragon's circle, and has been in active eruption some four or five times during the life of one of the present elders, at a few hours at a time, and the stones thrown out on each occasion have caused the hill to increase in bulk. Whenever the eruptions took place at the Nagah Bwai hill, the same strong smell of earth-oil was perceivable; the last eruption took place about five years ago. Some of the stones found at the spot where the last upheaval of the earth occurred have been collected by myself personally, and as the Officers of the Geological Department expressed a wish to have some of these stones, I forward the same, as they may cast some light on the causes that influenced this phenomenon of nature.

There seems to be little reason to doubt that earth-oil in one form or another was the disturbing influence.

ON BRAUNITE, WITH RHODONITE, FROM NEAR NÁGPUR, CENTRAL PROVINCES, by
F. R. MALLET, F.G.S., *Geological Survey of India.*

Some time ago, Mr. W. Ness, Mining Engineer in charge of the Warora Collieries, sent a parcel of about 20 lbs. of manganese ore to the Geological Museum, with a notice of the locality in which it had been found. It appears from this that the ore occurs on the south-east side of Munsur Great Trigonom-
metrical Station, a hill three miles west of the town of Rámtek, which is about twenty miles north-east of Nágpur. Mr. Wilson, Executive Engineer of the Kanhán Division, who has visited the place, describes the outcrop, which strikes north-west, south-east, as being visible for about a quarter of a mile, with a thickness of about 10 feet. Mr. Ness, however, is inclined to think that some portions are inferior to the samples sent to the Museum.

The latter are finely-granular massive, with here and there portions which are indistinctly crystalline on a larger scale. The specimens are bounded on two opposite sides by planes which appear to be joint-faces, approximately per-
pendicular to which the mineral is intersected by irregular, more or less elon-
gated cavities: the larger of these are about an eighth of an inch across, and some as much as three or four inches long: others are visible only under the lens. Many of them are partially, or almost entirely, filled by a translucent, light brownish-red and yellowish, indistinctly crystalline mineral, which proved on examination to be rhodonite.

The color and streak of the manganese ore are brownish-black. Hardness about 6·0. The specific gravities of three different samples were 4·22, 4·36, and 4·46, the differences (and the inferiority in gravity to that of braunite in crystals) being doubtless partly due to minute cavities.

On analysis the mineral yielded, counting all the manganese as sesquioxide, according to the formula more usually adopted for braunite—

Manganese sesquioxide	...	...	...	78·64	79·39
Iron sesquioxide	...	...	...	9·78	9·87
Lime	...	...	...	1·20	1·21
Magnesia	...	...	...	tr.	tr.
Oxygen in excess of that required for $M^2 O^3$	...	...	...	1·65	1·67
Silica	...	...	...	6·00	6·06
Phosphoric acid	...	...	...	·21	·21
Combined water	...	...	...	2·61	2·63
Hygroscopic water	...	...	...	·60	...
Disseminated rhodonite	...	...	...	·35	...
				101·04	101·04

The second column gives the composition exclusive of hygroscopic moisture and thodonite, scattered minute grains of which can generally be detected by the lens even in the most homogeneous specimens. Being but little acted on by

hydrochloric acid, it is left undissolved, together with gelatinous silica. The excess of oxygen, and the presence of water, show that the braunite is not in a pure state, having probably undergone partial alteration.

The ore contains 55.27 per cent. of manganese and 6.91 of iron. The main use of manganese ores, however, is as oxidizing agents, their value depending on the amount of available oxygen they contain. Pyrolusite, or peroxide of manganese, the richest in oxygen and most valuable ore, contains when pure 18.39 per cent.; and ores are generally valued by the percentage of peroxide they contain, or more correctly speaking, the percentage of peroxide, to which the oxides they contain are equivalent in available oxygen. The average run of ores met with in commerce contain 60 to 75 per cent. of peroxide = about 11 to 14 per cent. of available oxygen. The Nágpur braunite contains 9.71 of available oxygen = 52.80 per cent. of peroxide. As an oxidizing agent, therefore, it cannot be classed as more than fairly good.

A deposit of the same class of manganese ore was found by Mr. W. T. Blanford in 1872, at the village of Kodaigowhan (near Khappa), 20 miles due west of Munsur, Great Trigonometrical Survey.

PALÆONTOLOGICAL NOTES FROM THE SATPURA COAL-BASIN, by OTTOKAR FEIST-MANTEL, M.D., *Palæontologist, Geological Survey of India.*

In the beginning of last year (1878) I had an opportunity of traversing from east to west a portion of the great Sâtpura coal-basin, with the special intention of collecting fossils at certain places. Taking as guide the last report on this ground¹ I started from the Gâdarwâra station, Mohpâni field, Great Indian Peninsula Railway, for the Mohpâni coal-field, of which a brief description was published² in 1870.

With assistance of the manager of the Mohpâni coal mines, Mr. Maughan, I was enabled to collect what fossils were to be got, which to some extent permitted of a comparison of the Mohpâni coal seams (in part at least) with some other known horizon of the Indian coal strata, as given in my recently published flora of the Talchir sub-division.³ I shall repeat only what is necessary for general understanding in the present paper.

In the report referred to, the close relation of the Talchirs and the coal beds in the Mohpâni coal-field is pointed out; and this view seems to be supported by the fossils, which bring these coal seams on the horizon of the Karharbâri coal beds, which latter were recently shown to belong to the Talchir division.

The fossils which I collected were found in a band of shale in the uppermost of the Mohpâni coal seams, which are outcropping in the valley of the Sitariva river, on the right bank of which the only mines of importance at present are situated.

¹ H. B. Medlicott : Mem. Geol. Surv. of India, Vol. X.

² H. B. Medlicott : Rec. Geol. Surv. of India, Vol. III.

³ Pal. Indica, Ser. XII, 1.

The fossils are few in species, although numerous in specimens, and I could observe—

Equisetaceous stalks, some of which, I think, are of *Schizoneura*; *Gangamopteris*, pretty frequent, both in the original form *G. cyclopteroides*, and as a variety, *i. e.*, *G. cyclopteroides*, var. *attenuata*. *Glossopteris* almost equally numerous as *Gangamopteris*.

This distribution of the fossils appeared to me to be similar to that in the 3rd seam of the Kaharbári coal-field, and as I endeavour to show in the paper referred to that this seam also is to be considered as belonging to the Karharbári beds, there would be no objection to the Mohpáni seams being considered also as on the horizon of the Karharbári beds.

From Mohpáni I moved towards Pachmari, over ground formed of Parasuchian crocodile at Mr. Medlicott's Bágra and Denwa groups. Close to Jhirpa. Jhirpa, on the right bank of the Denwa, a specimen of a large scute of a *Parasuchian* crocodile was picked up by Mr. Hughes two years ago, and it was therefore my object to examine the place, if more remains could be found. I followed the river for some distance in north-western and western direction, but not a fragment could be discovered; so I crossed the Denwa and moved on to Singanáma, on the road from Bankheri to Pachmari, quite close to the boundary between the Denwa group of rocks and the next lower group, the Pachmari sandstone.¹ To the east of Singanáma, about 1½ mile, in the gorge of the Denwa,

the rocks are fully exposed, and a little to the south of the village Moár, on the right bank of the river, the junction of the Pachmari and Denwa groups is well seen, when it is clearly observed that the Pachmari sandstone dips without any unconformity beneath the Denwa group with the same northerly dip. From Moár I went all along the Denwa valley to the north, back to Jhirpa, in search of fossils in the Denwa group, but also this time nothing was found. There is only one more locality where some organic remains were found in the Denwa group, *i. e.*, far to the west near Kesla on the road from Shápur to Itársi, where Mr. Medlicott procured

Plant remains in the some plant remains in a very crumbling mottled shale, Denwa group. which, after close examination, proved to belong to *Glossopteris*. This is all our palæontological knowledge of the Denwa group up to date.

Proceeding from Singanáma to the south-west towards Pachmari, the ground rises rapidly up to the Pachmari plateau, which has an elevation of 3,481', the surrounding hills, specially to the south and south-west, being much higher, rising to 4,384' in the Mahádeo hill,

Pachmari sandstone.

¹ I may perhaps mention, that before crossing the Denwa river near Jhirpa, I was encamped at Mauljhar on the road from Chindwára to Bankheri, to the south-east of which near Anoni-Dhána, there is a hot spring with exhalations of inflammable gas; it is at the head of a small nalla which receives its water from this spring, which is pretty strong, and the gas escapes at about ten places; at the source the water had a temperature of 130°F.; below this it is collected in a sort of a small tank, where it shewed 102°F., and from here it passes into the nalla. It is, of course, in high estimation with the natives, and close to it is a primitive temple of Mahádeo with a Jogi in attendance.

to 4,317' in the Cháoradeo, and to 4,454' in the Dhupgarh. Close to Singanáma we pass from the Denwa group on to the Pachmari sandstone, of which the whole Pachmari plateau as well as the mentioned hills consist. This Pachmari sandstone proved, in spite of careful examination, unfossiliferous.

Proceeding from Pachmari southwards, the road, always over Pachmari sandstone, leads close by the Mahádeo hill, passing the famous Mahádeo cave in the northern flank of the hill; from this cave the descent into the upper valley of the Denwa is very rapid, down the steep and abrupt slopes of the southern side of the plateau. About $1\frac{1}{4}$ mile before reaching the Denwa the slope becomes more gentle, and before reaching the police station at foot of the Pachmari range (which is about $\frac{3}{4}$ of a mile from the Denwa) there is a change of rocks, *i. e.*, under the Pachmari sandstone there appear soft, sandy, micaceous shales of greenish, yellowish, or brownish-yellowish colour, which apparently have

Shales under Pachmari the same northerly dip as the overlying Pachmari sandstone.

stone; that this is the case I have found further on. Here these shales proved unfossiliferous. Similar shales occur further to the north-west near Almod and Rorighát, where they were found to contain only some indistinct plant impressions.

In his report on the Sátapura basin, Mr. Medlicott, speaking of his Bijori horizon, mentions two possibly different bands, of which the higher might be distinguished as Almod beds; and it appears to me that the shales which I just mentioned as cropping out under the Pachmari sandstone might possibly represent these Almod beds; because, when proceeding further to the south close to the Denwa river, the shales change somewhat in appearance, they become a little harder, greyish and grey colours appear, and they are fossiliferous. In position they are lower than the shales mentioned before, both having the same dip. To have a better opportunity and more time to collect fossils I crossed the Denwa river near Sangakhera Dhána and encamped at Barikondam, where I was also close to the spot where the reptile said to be *Archegosaurus* was found in this lower horizon.

The place where I collected fossils in the shales lies directly to the north of Fossil plants in the Bijori Barikondam, on the left bank of the Denwa river, between this and the police station at the foot of the

Pachmari range. The shale crops out at the base of a small hill, on the eastern slope of which the road from Pachmari leads to the Denwa river, cutting through shales containing fossils. A little to the east of this hill, but still before crossing the Denwa river (coming from Pachmari), in a small nalla which the road has to cross, an instructive section is exposed showing the relation of the strata south of the Pachmari range to the Pachmari sandstone, as follows, in ascending order:—

- a. Dark-grey carbonaceous micaceous shales dipping north at about 15° , containing *Vertebraria*.
- b. Greenish-reddish shales slightly micaceous.
- c. Coarse thin-bedded sandstones, with the same northerly dip.

Above these sandstones is a series of sandy micaceous shales, which in this place contain no fossils, but which I believe to be the same as those at the base of the hill mentioned as on the left bank of the Denwa (north of Barikondam) where I obtained fossils; above these sandy shales is a bed of fine earthy bluish-grey or reddish-grey shales with plant fossils. Above these there would come in the sandy micaceous shales which I mentioned before as immediately below the Pachmari sandstone, and then these sandstones themselves, all apparently with the same dip. I obtained the following fossils from these localities :—

a. From the base of a small hill on the left bank of the Denwa river north of Barikondam in brownish-yellow, greenish-yellow, sandy and earthy micaceous shales which do not split regularly; the fossils are plants only and very fragmentary—

Glossopteris communis, Fstm.

Glossopteris with horizontal broad meshes (called in manuscript *Gl. damudica*).

Glossopteris, another form with distinct polygonal meshes, which form occurs also in the Rániganj group of Bengal, and which will be described as *Gl. retifera*.

Pecopteris comp. *angusta*, H. (*Merianopteris angusta*, H.). This species occurs in the Trias of Europe. A form of the same genus is known also from the Rániganj group.

Diksonia (comp. *Concinna*), a form which appears to me to be the same as that found by Mr. Hughes in the Rániganj group of the Jherria coal-field, and figured by me in 1877.¹

b. To the east of the place just mentioned fossils were found, as already stated, in fine earthy light grey, bluish-grey or reddish-grey shales which appear to me to be above these shales. The fossils were—

Equisetaceous stalks, of which some may belong to *Schizoneura*, as this genus was found in this horizon.

Vertebraria indica, Royle; small specimens.

Glossopteris predominant; different forms.

Glossopteris communis.

Glossopteris indica, Schimp. (one specimen with little oblong marks as if indicating the Sori).

Glossopteris with broad horizontal meshes (*Gl. damudica*).

Glossopteris leptoneura, Bunb.; narrow leaflets.

Gangamopteris, a form with small roundly ovate leaves.

A round winged seed of the genus *Samaropsis*, Göpp.,² much resembling Heer's *Samarops rotundata*.³

Some other small seeds, not winged, resembling very much seeds of the same kind from Damuda rocks in South Rewa, collected by Mr. J. G. Medlicott.

Besides these fossils collected by myself, there were some other specimens. Other fossil plants in the from the same district in our collections. One lot of Survey collections. about fifteen specimens was labelled, "Upper Denwa valley near Barikondam;" the fossils are plant impressions in an earthy-reddish

¹ Rec. Geol. Surv. of India, Vol. X.

² *Fructus samaroides, membranaceus compressus, margine alatus, monospermus.*

³ Heer: *Flora fossilis arctica*, Vol. IV; *Jura flora Ostsibiriens, etc.*, p. 80.

shale, and there is little doubt that they come from a similar bed of shales to that mentioned before as above the sandy micaceous greenish-yellowish shales with fossils. They comprise—

Schizoneura gondwanensis, Fstm. The same form as in the Rániganj, Jherria, and Hingir coal-field.

Glossopteris communis, Fstm. The same form as in other places.

Besides these there is a single specimen labelled “Denwa naddi, Pachmari.” It contains—

Trizygia speciosa, Royle (*Sphenophyllum trizygia*, Ung.), which chiefly occurs in the Rániganj coal-field (Rániganj group), in the Talchir coal-field (Barákar group), and is doubtfully quoted from the Damuda rocks at Paukabári.

There is no doubt that this specimen also comes from this fossiliferous zone of shales in the Bijori horizon in the Upper Denwa valley.

If we now consider the fossils mentioned above as coming from the Bijori horizon in the Denwa valley, *i. e.*, *Schizoneura gondwanensis*, Fstm., *Trizygia speciosa*, Royle, *Vertebraria indica*, Royle, *Glossopteris* in various forms, *Pecopteris angusta*, H., etc., we find that all these occur also in the Rániganj group in Bengal, so that the fossiliferous band is correctly considered as representative of this group in the Sátpura coal basin, in which case those sandy micaceous unfossiliferous shales immediately below the Pachmari sandstone, and the beds of the same position near Almod and Rorighát (which have been distinguished as Almod beds), would perhaps represent the Panchet group of Bengal, this the more if we consider the close relation of this group in Bengal with the Rániganj group, and the much smaller number of fossils in the former than in the latter.

I made also a search from Barikondam to the west, at and round the spot where the said *Archegosaurus* was picked up by Major Bijori horizon. Gowan;¹ but no trace of any fossil was found in the Bijori sandstone.

Fine earthy sandy-micaceous greenish-yellowish shales were observed, as Shales at Almod and Rorighát. already mentioned, near Almod and Rorighát; except indistinct marks, they were found otherwise unfossiliferous, and they appear to be the same as those mentioned before as immediately underlying the Pachmari sandstone.

Further to the west, however, on the road from Rorighát to Shápur (by Plants between Rorighát Harapála, Jhuli, &c.), about five miles from this place, and Harapála. I found in a nalla some shales containing plant remains.

¹ Journ. As. Soc., Beng., XXXIII, 1864, pp. 336, 442.

They are dark greenish-grey, rather hard, slightly micaceous. The fossils were not many, but sufficient to indicate the horizon. I collected—

Schizoneura gondwanensis, Fstm. One leaf.

Vertebraria indica, Royle. The more branched thinner form, like that in the Kámthi beds of the Rániganj group.

Glossopteris leptoneura, Bunb.

Glossopteris, another species.

The fossils of this locality agree therefore with those mentioned before from the Denwa valley, and can be like these considered as on the horizon of the Rániganj group.

The next observations were of the Damuda rocks and outcropping coal seams in the neighbourhood of Shápúr. A full report on this Shápúr coal-field. field was published by Mr. Medlicott in 1875;¹ my object was directed to the examination of the outcrops for their fossils.

In this coal-field also, like in that of Mohpáni, Mr. Medlicott points to the close relation of the coal beds (Barákar group) to the underlying Talchirs (*l. c.*, p. 76), and this conclusion from stratigraphical grounds is perhaps also supported, partly at least, by the few organic remains. These are again plants only, and I think they partly show the existence of representatives of the Karharbári beds, indicating the close connection of these coal beds with the Talchirs.

I first visited the outcrops in the Machna river, north-east of Shápúr. The coal crops out at two places; in both some fossils were found which tend to indicate two horizons. The more north-eastern outcrop is close to the village Mardánpur, in the river bed; there are two outcrops running Mardánpur outcrops. parallel, one on the right and the other on the left bank of the river, but only that on the right bank appears of any importance, and when I was at this place a very primitive kind of mining (digging) was going on on this outcrop.

The dip is 30°, to north-west-by-north. This lower outcrop only was accessible for examination. The whole outcrop (shales included) measures 4 to 5 feet, dipping under white, open and rather coarse-grained sandstones. The coal itself is at this place not thicker than about 2', being overlaid by coaly shales and underlaid by grey sandy shales, and in the coal itself there is a good deal of what is called fibrous anthracite.

The fossils at this place were very scarce: I found in the coal impressions of Fossils. *Vertebraria*, and also in the underlying shales some impressions were observed which appeared to me to belong to the same genus.

From these outcrops to the south-west up the river, we find other outcrops at the bend of the river west-south-west of Kotmi. The Kotmi outcrops. outcrop here passes from east to west across the river,

¹ Rec. Geol. Surv. of India, Vol. VIII.

and is better exposed on the left bank. The strata dip north-east-by-north, at about 15° . The sequence of strata on the left bank is the following (in descending order) :—

- a. Uppermost sandstones.
- b. Yellowish-brownish-grey sandy shales.
- c. Grey earthy-sandy shales with *plants*.
- d. A band of very fine earthy carbonaceous brownish-black shales with *plants*. They contain also much pyrites.
- e. The coal seam about 2 to 3 feet thick.
- f. Shales and sandstones partly already in the river.

On the right bank there appears under these sandstones another bed of carbonaceous shales without coal. Fossils occur in the upper part of both these outcrops.

On the right bank I found in the grey sandy shales—

Glossopteris, fragmentary, and
Nöggerathiopsis (*Hislopi* ?), fragments.

On the left bank were found—

- a. In the black shale immediately above the seam—

Glossopteris, fragments.
Gangamopteris and *Nöggerathiopsis*.

- b. In the sandy grey shales above—

Equisetaceous stalk.
Glossopteris communis.
Gangamopteris cyclopteroides, Fstm., several specimens.
Nöggerathiopsis hislopi.
Some small seeds (*Carpolithes*).

Here, therefore, were found more fossils than in the Mardánpur outcrops, and they perhaps indicate the horizon of the Karharbári beds.

From here I went to see the outcrops in the Táwa river near Temni (on the map, but by the people called Temru); no fossils were found in the shales, which appeared to me to have a resemblance to Talchir shales; they perhaps represent, as Mr. Medlicott (*l. c.*, p. 80) suggests, the outcrops at Kotmi.

In the outcrops north of Shápur in the Suki river before it falls into the Táwa river, only very few and fragmentary fossils were found. In the lower beds of carbonaceous shales, I found fragments of *Equisetaceous* stalks and of *Nöggerathiopsis*, and in the upper one a fragment of *Nöggerathiopsis*. The beds dip to north-east-by-north at 10° .

There is no direct indication for a comparison of these outcrops with any of the others, the fossils being so very scarce, except perhaps from the position with the outcrops in the Bhoura naddi (near Sonáda).

About nine miles south-east of Shápur there are other outcrops in the Táwa river near the village of Dolári. Going from Dolári to the river and passing down it to the east, we meet the first (or lowest) seam No. I; it is underlaid by sandstones, and the following rocks are seen—

- a. Brittle, sandy, greenish grey micaceous shales.
 - b. The coal seam about 2' thick at this place, the coal, however, brittle and full of the fibrous anthracite.
 - c. Thin-bedded shaly sandstones.
 - d. Thin sandstones again up to the next seam.
- No fossils were found in this outcrop.

We pass then from here eastwards over sandstones which become thin-bedded and shaly, until carbonaceous shales of 4'—5' appear, without coal; above these shales some sandstones, and then again dark-grey shales are seen, under which lies the seam No. II, which, however, was then covered; but I saw at Dolári some old heaps of coal, which was said to have been dug from this seam. In the outcropping grey shales some fossils were found, although very fragmentary—

Equisetaceous stalks.

Gangamopteris cyclopteroides, Fstm.

Glossopteris.

Nöggerathiopsis hislopi, Bunb., sp.

These fossils, although very scarce, yet perhaps permit of a comparison of this outcrop with that near Kotmi, and consequently also with the Karharbári beds. Here at Dolári, however, all the outcrops are so close to each other that they may well be considered as representing all the same horizon.

The IIIrd outcrop (to the east) was almost entirely covered by river sand. I procured only with great trouble a piece of coal which was of very inferior quality; but the thickness of the seam could not be ascertained.

The highest and last outcrop, the IVth, to the east, is exposed to some extent. On the underlying sandstones appear thin-bedded carbonaceous micaceous shales with fragmentary fossils, then the coal seam about 2' thick (at this place); then shales and sandstones. The only fossils I could observe were fragments of a *Glossopteris*.

As the last to be mentioned are the outcrops about eight miles to the north-west of Shápur in the Bhoura naddi (also Suk-Táwa), close to the village Sonáda. There are several outcrops three quite close to each other in the northerly bend of the river at the village, but they are much concealed, and no fossils could be procured. It would, however, not appear improbable that some of these outcrops at Sonáda represent those in the Suki river north-east of Tekripura.

On my return way from Shápur to Itársi (Great Indian Peninsula Railway) I made a search round Kesla in the Denwa group. I think I found the decomposed mottled shales from which *Glossopteris* had been procured; but to my regret failed to find any fossils.

I may now mention that all these sedimentary rocks of the Sâtpura coal-basin (south of the Narbada) constitute an unbroken series of beds of the Gondwâna system from the Talchirs (the lowest) to the Jabalpur group (the highest), all being generally conformable, or very nearly so. The Jabalpur group, the Bâgra-Denwa group, and the Pachmari sandstone form the upper portion of the Gondwâna system, while the beds from the shales immediately under the Pachmari sandstones down to the Talchirs constitute the Lower Gondwânas.

The Lower Gondwânas in the Sâtpura basin can therefore perhaps be classified thus—

- | | | |
|--|--|-----------------------|
| a. The shaly beds immediately below the Pachmari sandstone south of the Mahâdeo hill near Almod and Rorighât; soft, earthy and sandy micaceous shales, greenish-yellowish, with indistinct plant remains. They may, as proposed by Mr. Medlicott, well be distinguished as Almod beds. | Probable representatives of the Panchet group. | Panchet sub-division. |
| b. Mr. Medlicott's Bijori horizon. Sandstones with shales, some of them carbonaceous and fossiliferous. | Represent the Kâmthi-Râniganj group. | Damuda sub-division. |
| c. Mr. Medlicott's Motûr horizon | Ironstone shales? ... | Ditto. |
| d. Barâkars: tûr of the coal-beds in the Shâpur coal-field. | Barâkars | Ditto. |
| e. Karharbâri beds in the Mohpâni coal-field and some of the seams (near Kotmi and Dolâri) in the Shâpur coal-field. | Karharbâri beds | Talchir sub-division. |
| f. Talchir group in the Mohpâni and Shâpur coal-field. | Talchir group elsewhere | Ditto. |

I may add at end the relations of the several horizons as regards their fossils—

- a. Jabalpur group: fossiliferous, plants only, of middle jurassic type (but also *Glossopteris* from the Sher river).
- b. Bâgra group (H. B. Medlicott): no fossils known at present.
- c. Denwa group: a scute of a *Parasuchian* crocodile from near Jhirpa (on the Denwa river) and some plant fragments (*Glossopteris*) from near Kesla.
- d. Pachmari sandstone: no fossils known at present.
- e. The shales immediately below the Pachmari sandstone: indistinct plant impressions (Almod beds).
- f. Bijori horizon: shales with stalk remains: *Equisetaceous* stalks, *Schizoneura*, *Glossopteris*, *Pecopteris*, &c.

In the sandstones was found a portion of the skeleton of a reptile said to be *Archegosaurus*.

- g. Motûr horizon: no fossils known up to date.

- h. Barákars : some plant remains in the Shápúr area (*Glossopteris* and *Nöggerathiopsis*).
- i. Karharbári beds : in the Mohpáni coal-field and in the Shápúr area : *Equisetaceous* stalks, *Gangamopteris*, *Glossopteris*, *Nöggerathiopsis*.
- k. Talchir beds : no fossils found in this district.

STATISTICS OF COAL IMPORTATIONS INTO INDIA, by THEO. W. H. HUGHES, *Geological Survey of India.*

In the leisure of my leave on furlough I have attempted to gather some particulars on the Indian imports of coal and coke, which will, I think, be of interest and perhaps of some little value to those readers of our Records who are concerned about the mineral statistics of India. I had myself so often experienced the want of some readily accessible reference, which should contain in a connected form information on this subject, that I was emboldened to undertake the task of arranging such data as I could bring together, by the knowledge that I should be relieving others of that want. For a large portion of the details here given, more especially those relating to the earlier years, I am indebted to various abstracts and reports published by the Board of Trade and placed at my disposal by Mr. Robert Hunt of the Mining Record Office; for the rest, I have to acknowledge my obligation to Mr. Charles Prinsep of the Statistical Department, India Office.¹

The annual consumption of fuel for sea-going and river steamers, for railways, for factories, and for other purposes has within the last year or two grown to something between 900,000 and a million tons, and of this amount it may be roughly said that one-half is foreign coal. However much this circumstance is to be regretted by those who are interested in the development of our own fields of supply, there appears to me to be small chance of a diminution in the ordinary rate of importation until native coal is lightened to some extent of the heavy burden of charges imposed by land carriage and by freights, so that it may compete on more favorable terms than at present with its rivals at the western ports of the Bombay Presidency, and those of Madras and Burmah. Our three principal coal mining districts, Rániganj, Karharbári, and the Wardha valley, are so situated that the item of railway transport alone—even in the case of the two more favourably situated fields, the Rániganj and the Karharbári—trebles and quadruples the actual costs of the coal by the time it reaches a port for shipment; and it utterly prohibits the sale of the produce of the Warora colliery (Wardha valley) within a distance of 200 miles of Bombay.

Beginning with the year 1853, the shipments of coal and coke to India were 43,562 tons. Since then, after the lapse of a quarter of a century, they have risen to 609,735 tons. The ratio of increase has not been by any means steady : wars,

¹ Without Mr. Prinsep's assistance I should have found my undertaking a more tedious affair than I at first imagined it. The labor involved in dealing with figures is very inadequately represented by the printed space they occupy.

rumours of wars, famines, and improved home freights have always exercised an irregular influence ; as during the past two years, the importation having jumped from 399,887 tons in 1876 to 539,533 tons in 1877, and to 609,735 tons in 1878. Had not disturbing causes, such as the Madras famine and the anticipations of war, been at work in 1877, it is probable that the imports of coal for that year would not have amounted to more than 420,000 tons ; and under peaceful conditions, the figures for 1878 would have been considerably less than they actually were. Our main supply of foreign coal has hitherto been derived from the United Kingdom, the contributions furnished by other countries, with the exception of Australia and France during spasmodic periods, being insignificant. The tonnage of imports for all India, from all countries, commencing with the year 1853, is as follows :—

TABLE I.—Imports of coal and coke to India from 1853 to 1878.

Years ending 30th April	1853	Coal and Coke	...	43,562
	1854	"	...	58,410
	1855	"	...	41,987
	1856	"	...	76,712
	1857	"	...	82,078
	1858	"	...	92,983
	1859	"	...	99,701
	1860	"	...	74,263 <i>a</i> .
	1861	"	...	...
	1862	"	...	174,862 <i>b</i> .
Years ending 31st March	1863	"	...	122,722
	1864	"	...	189,611
	1865	"	...	216,985
	1866	"	...	228,319
	1867	"	...	257,652 <i>c</i> .
	1868	Coal	... 368,618 }	385,331
		Coke	... 16,713 }	
	1869	Coal	... 332,718 }	348,926
		Coke	... 16,208 }	
	1870	Coal	... 315,935 }	337,023
		Coke	... 21,088 }	
	1871	Coal	... 269,396 }	286,180
		Coke	... 16,784 }	
	1872	Coal	... 361,960 }	374,184
		Coke	... 12,224 }	
	1873	Coal	... 310,265 }	324,643
		Coke	... 14,378 }	
	1874	Coal	... 354,231 }	359,903
		Coke	... 5,672 }	
	1875	Coal	... 360,251 }	366,539
		Coke	... 6,288 }	
	1876	Coal	... 389,480 }	399,887
		Coke	... 10,407 }	
	1877	Coal	... 523,384 }	539,533
		Coke	... 16,149 }	
	1878	Coal	... 603,904 }	609,735
		Coke	... 5,831 }	

(a) The returns are qualified by the statement "as far as can be stated."

(b) For this year the returns are not complete for Bengal.

(c) For eleven months only.

In the following table the quota of *coals* annually supplied by each country is given for the years 1870 to 1874 inclusive, but for the succeeding periods to 1877, I have only noted the larger contributions. It will be understood that under the head of Holland, Mauritius, Red Sea, Aden, Ceylon, and the Straits, it is "transit coal" and not "indigenous coal" that has been exported for India:—

TABLE II.—*Imports of coal to India from various countries from 1870 to 1877.*

	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
United Kingdom...	301,864	257,914	348,725	287,813	330,635	339,821	359,680	491,318
Australia ...	12,607	8,942	5,917	1,511	14,677	4,652	6,130	798
France ...	415	1,241	454	17,902	5,676	...	156	1,111
Germany ...	10	250	5,007	1,613	1,710	660	...	500
Mediterranean ports	...	...	...	...	275	...	...	...
Holland ...	...	...	102	...	...	...	...	...
Russia ...	...	500	...	...	...	...	...	...
America ...	460	...	...	441	799	687	130	2,146
Mauritius ...	...	103	...	...	...	...	...	...
Red Sea ...	...	...	...	...	50	...	...	...
Aden ...	...	120	187	136	98	...	...	...
Ceylon ...	420	363	1,386	218	207	...	...	...
Straits ...	...	...	...	187	74	...	...	...
Java ...	...	...	...	400	...	...	802	400
Other countries ...	159	188	182	44	30	...	...	...
Total ...	315,935	269,396	361,960	310,265	354,231	...	...	...

During the last year, the shipments of Australian coal have fallen off seriously ; and I think we have now seen almost the last attempt to force it into the Indian market. For the sake of reference, I give the imports for the 20 years ended 1877:—

TABLE III.—*Imports of Australian coal to India from 1857 to 1877.*

	Tons.		Tons.
1857 to Bengal ...	2,271	to Bombay ...	2,176
1858 ...	14,061	...	8,998
1859 ...	4,278	...	2,293

TABLE III.—Imports of Australian coal to India from 1857 to 1877.—contd.

	Tons.	Tons.
1860 to Bengal ...	10,008	to Bombay ... 8,112
1861 (a). ...	...	... 12,045
1862 ...	7,191	... 5,649
1863 ...	...
1864 ...	13,292	
1865 ...	5,207	
1866 ...	6,376	
1867 ...	7,465	
1868 ...	5,792	
1869 ...	9,257	
1870 ...	12,607	
1871 ...	8,942	
1872 ...	5,916	
1873 ...	1,511	
1874 ...	14,677	
1875 ...	4,652	
1876 ...	6,130	
1877 ...	798	

(a). Returns for Bengal not given for 1861.

To illustrate the distribution of the imports to the five great Provinces of India, I have selected the years from 1870. Bombay is by far the largest receiver; the cotton-mills of the city of Bombay and the railways having their terminuses there being heavy consumers of foreign coal. In Bengal the railways and nearly all the steam-mills burn exclusively the produce of the better seams of the Rániganj field and those of the Karharbári field:—

TABLE IV.—Imports of coal to different Provinces of India from 1870 to 1877.

	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Bombay ...	239,651	167,257	220,884	208,269	216,543	219,836	260,080	368,937
Bengal ...	42,443	63,929	89,775	48,638	82,120	63,821	61,091	76,278
Burmah ...	20,198	26,731	39,981	36,715	27,071	33,301	38,397	47,770
Madras ...	11,648	9,053	9,390	15,513	25,043	12,155	20,275	22,544
Sind ...	1,995	2,426	1,930	1,079	3,454	1,138	9,637	7,855
Total ...	315,935	269,395	361,960	310,264	354,231	360,251	389,480	523,384

Though Aden and Ceylon do not come within the official limits of India, I append the few following statistics for comparison:—

TABLE V.—*Imports of coal to Aden and Ceylon from 1866 to 1876.*

	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.
ADEN—											
Coal ...	70,361	115,572	106,265	62,610	67,546	87,394	85,158	75,569	?	74,797	99,423
Patent fuel	17,713	5,630	10,462	15,027	13,318	13,434	11,968	13,106	?	3,486	5,951
CEYLON—											
Coal ...	63,174	86,206	67,589	?	?	107,625	62,555	76,132	?	74,083	81,789
Patent fuel	8,579	2,702	9,647	4,412	14,446	11,436	6,076	4,769	?	...	...

Patent fuel figures to some extent amongst the imports to Madras and Bombay, but the amounts of late years have been quite insignificant.

LONDON, *December 1878.*

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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 2.]

1879.

[May.

NOTE ON THE MOHPÁNI COAL-FIELD, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

No ground in India has been so frequently noticed in these pages as the Mohpáni coal-field,¹ situated on the south side of the Narbada valley, 95 miles by rail below (west-south-west of) Jabalpur, and at the northern edge the Sátpura basin of the Gondwána rocks. It owes this distinction to three circumstances: first, to its position, close to one of the great trunk lines of railway, and as the nearest open source of coal to north-western India; its distance from Allahabad is 322 miles, or 83 miles nearer than the Karharbári field, from which all the coal for the line up to Delhi and Lahore is at present drawn;² and its distance from Kandwa, the junction of the Indore and Neemuch line, is 196 miles, or 122 miles nearer than the Warora colliery to the same point.

The second circumstance which gives importance to Mohpáni is, that it is the only easily accessible coal-field in this region. It has been known from the first that the only outcrop of the coal-measures along the northern edge of the Sátpura basin is at Mohpáni; and the failure of the boring experiments made during the past four years, under orders of Government, and of which an account has been published in the papers referred to above, has fairly established that the coal is not within easy reach at any other point along that line—a conclusion which indirectly gives an indefinitely increased value to the Mohpáni field.

The third circumstance which has brought Mohpáni so frequently under official notice is, the possibly precarious nature of the supply in that field. The long protracted doubt on this point has been entirely owing to the timorous and

¹ Mem. G. S. I., Vol. II, Pt. 2, 1859; Vol. X, Pt. 1, 1873. Rec. G. S. I., Vol. III, Pt. 3, 1870; Vol. IV, Pt. 3, 1871; Vol. V, Pt. 4, 1872; Vol. VIII, Pt. 3, 1875.

² The opening of the Palamow fields, *by the most direct line*, would remove this advantage.

inefficient management of the mining operations, especially for works of exploration, by the Narbada Coal Company, within whose property the known field lies. The mines were started at or close to the outcrop in the Sitariva river and within a short distance, in both directions, the coal was found to be cut out against two intersecting planes of faulting, the calculable amount of coal being, of course, limited to what lay in the small triangular area between these planes and the outcrop. There never was any reasonable doubt that the coal did occur outside these faults in one or other direction, or in both; and confidence in the resources of the field was sufficient to guarantee the construction of a full-gauge branch railway, 13 miles long, from Gádarwára to the pits; still, as time wore on, the urgency of proving the extent of the field became more and more pressing, so as at least to be prepared to break fresh ground before the original small block of coal-measures became exhausted.

There were two directions for these explorations: one to the south-east, to the dip of the measures, towards the main area of the basin; the other to the north-east, on the local strike of the measures. The objections to the latter ground were, that the disturbance of the rocks, already a sufficient difficulty in the existing workings, was known to be indefinitely greater to the north; and, that being also the direction of the edge of the basin, there was an extra presumable risk of original banking out of the seams. The fear in the other direction was that the measures might be let down to an inaccessible depth; but of this opinion there was no confirmation in the outcrops, which are fairly exposed in the bed of the river. These considerations were repeatedly, but ineffectually, urged upon the mining administration. The ground to the north-east was superficially the easier to explore, and efforts were chiefly spent upon it, but without the smallest success. Borings were also attempted to the south, and even a new shaft begun in that direction; but in no case was the trial carried far enough to touch the coal, even at the depth calculated from the dips, without any allowance for possible small downthrow.

When I visited the field in December 1876, in company with Mr. Hughes, the uncertainty was still pending, no advance having been made with the exploration, and the original block of measures was being rapidly worked out. The trials in other parts of the Sâtpura basin were then in progress, but hopes of success were waning, and altogether the prospects of mining enterprise in this part of India seemed at its lowest ebb. When in October 1878 the last experimental trial outside the Mohpáni field had failed to prove coal, the necessity for a proper exploration of the ground within that field became imperative. To urge this point, and to see what had been done since the close of 1876, I visited the collieries in March of this year.

It was said above that there never had been any valid doubt upon the extension of the seams to the south-east; that there was no evidence for the supposition of a great fault, throwing the measures down out of reach on that side; still, until the ground was proved, anxiety could not be altogether allayed. In 1870 (see Recs. Geol. Surv. India, Vol. III, p. 69), I pointed out that "the best means of immediately testing the southern extension of the measures is from shaft No. 2," which had been long since abandoned on account

of the influx of water when the coal was reached. In December 1876 an attempt was being made to fix pumping gear in this shaft; and the new manager, Mr. J. A. Maughan, M. E., who took charge of the mines at the beginning of 1877, seems to have pushed on this work with vigour, for on the occasion of my recent visit, in March last, I found that all the coal that was then being raised was by this shaft, from workings to the south, extending to about 350 feet from the shaft, beneath the covering Mahádeva rocks, and quite beyond the presumable position of any great east-west fault. In these new workings the main (30') seam is in full force, and also the lower seam.

Thus whatever apprehension may have existed regarding the supply of coal in this field may be laid aside. The condition of the seams in the new ground opened by Mr. Maughan gives every reasonable expectation of an abundant supply, within a moderate depth from the surface.

Still the difficulties of the enterprise are not at an end. The evil effects of protracted neglect of system and forethought are not to be overcome in a moment; and the output of the colliery cannot be counted upon with any certainty until those defects are removed, and a proper system of mining established. As has been already stated, all the old openings, shaft No. 2 amongst them, are at or near the outcrop of the seams, so that the coal lies chiefly at a lower level than in the shaft; and the dip of the seam being still considerable and variable, the difficulties of raising the coal and of draining the mine increase rapidly as the work advances. Until a new shaft is in working order well to the deep of all the present openings, a large and regular output of coal cannot be depended upon.

Notice may here be given of the concluding operations in search for coal outside the Mohpáni field, in continuation of that given in the Annual Report for 1877 (Rec. Geol. Surv. Ind., vol. XI, p. 7). The Anjan boring, mentioned as then in progress, was carried to a depth of 350 feet (11th May 1878) without piercing the covering red rocks of the Mahádeva series. This was the last trial to find the coal-measures in proximity to the detached inliers of the Talchirs.

There remained but one position favorable for a trial, and where, I must confess, I looked with very great hopes for success. It is close to the south-east of the village of Baner, or Benár, at the very edge of the Narbada Company's land, in ground formerly held by the Sitariva Coal Company, when a shaft had been begun, by my advice, at this spot.¹ It is less than half a mile from the seams in the Sitariva; an outcrop of coal-measure sandstone (or a rock undistinguishable from it) occurs north of the village, and the shaft begins in the red covering rock, so that unless the coal dies out within that short distance, or some undetected unconformity occurs between the formations, there seemed a certainty of striking the coal here, and I recommended to Government that a boring should be put down in continuation of the old shaft.

This boring commenced on the 24th February 1878, the water and mud having been cleared from the shaft, which was found to be 118 feet deep,

¹ See Rec. Geol. Surv. Ind., Vol. IV, p. 68.

and the bottom 13 feet, which was not walled, consisted of purple clay, brittle and falling off in flakes. At 179 feet the red rocks were passed through. The dip and the distances from the boundary not being accurately known, on account of the covered nature of the ground, no exact calculation could be made; and in such massively-bedded rocks any such calculation could only be approximate; but at a probable estimate of a dip of 20° and a horizontal distance of 500 feet, this proved depth and thickness of the Mahádeva rocks is about what should occur under the assumed condition of conformity; and at least it proves that between this spot and the boundary there can be no great post-Mahádeva fault, with southerly downthrow.

At 179 feet the boring entered on sandstone, grey and white, felspathic, most like the coal-measure rock; and our hopes were very strong that coal would soon be struck, as, in the supposed normal section, it all lies within the top 150 feet of the measures. Carbonaceous shale and even fragments of coal appeared in some of the samples, but only to delude our hopes, for the boring was continued to a depth of 426 feet, or 247 through the lower formation, without any better result, so I recommended the work to be stopped.

In attempting to account for this section, several conjectures are apparent. It may be that the carbonaceous measures passed through are not the true coal-measures, but only the carbonaceous measures of the middle Mahádeva horizon, such as were found at Tundni, eight miles to the west; but the total absence of such beds in the clear section in the Sitariva, within half a mile of the boring, makes this supposition the least probable. There is then the possibility that within this short distance the coal seams may have died out; this is the most unfavourable view of the case, and one that seemed unlikely, considering the great regularity of the bottom seam in the lower mine, north of the river; but it is a chance that must not be lost sight of in our Indian coal-fields, especially in these lower measures; indeed, in this same bottom seam, I have observed something very like an original extinction, in the section of the "new incline," where the coal passes rapidly into a sandy shale, never having come to the surface on the rise of the little hill. A third supposition is, that the boring chanced upon a band of disturbance, and so passed down between the broken and displaced seams. The mixed nature of the samples at and below a depth of 325 feet gave some support to this supposition, and it was the one I felt inclined to adopt.

The facts disclosed by the new working at the mines dispose me, however, to think that we have here to deal with original features of the deposits. The lie of the seams south of shaft No. 2 is not quite what would be inferred from the outcrops: the strike is more nearly due south; and in rising to the west the coal is stopped out against a steeper sloping face of sandstone. Mr. Maughan has had to deal with many slips and crushing of the seams in these new workings, but they have all proved only temporary obstructions, save this one on the west. To prove it thoroughly he had a boring put down from the surface at a point about 200 feet west of this stoppage. At 140 feet the red rocks were passed through; here again, as at Baner, this depth indicating the general conformity of the groups. Below 140 feet the bore passed through 270 feet of coal-

measure rocks, "grey post and blue metal," *i. e.*, sandstone and dark clay, to the total depth of 410 feet, without a sign of coal. We can hardly again have recourse to the conjecture of a space between faulted ends of the seams. The one supposition that meets all the local facts is that of original limitation.

I said above that this is the least favourable view to take, as of course if the interruption were only due to faulting, the recurrence of the seams could be counted on, whereas no diagnosis of the ground can do more than guess at variations of original distribution. I do not think, however, that there need be any alarm on this score for the immediate, or even for the distant future. I cannot but think that there must be a great store of coal beneath the Malpi (Mulpec) plain, and south of it up the valley of the Sitariva.

ON PYROLUSITE WITH PSILOMELANE OCCURRING AT GOSALPUR, JABALPUR DISTRICT, *by*
F. R. MALLET, F. G. S., *Geological Survey of India.*

The existence of manganese ore at Gosalpur appears to have been known for a long time past, and the mineral has been in use to some little extent amongst native glass makers in the neighbourhood. It was first brought to the notice of Government by Mr. W. G. Olpherts in 1875, to whom we are indebted for specimens subsequently received. Lately, the Deputy Commissioner, Colonel Playfair, has again called attention to this ore and asked for information regarding it. Within the last month Mr. Medlicott has visited the locality, and reports upon the deposit as follows:—

"The sections available for examination were very poor indeed, only shallow holes, 5 or 6 feet deep, along an irregular line some 20 yards in length, on the outskirts of the village of Gosalpur, at the base of the low ridge on which the dāk bungalow stands. The well in the village, from which also the ore was obtained, is at a slightly lower level, about 120 yards nearly due east of the shallow pits, but it was not available for examination. I have, however, satisfied myself that the deposit is not a vein or lode, and that it has no apparent connection with any vein or lode in the underlying transition rocks. It is not, either, a layer or bed in the formation in which it occurs, which is laterite, but is irregularly distributed throughout this rock in lumps of various shapes and sizes. These mostly have a spongy or cellular structure, but some pieces of very compact ore, more or less reniform, were found. This laterite is of the older type: at least in the exposed sections I could not detect any palpable debris, which generally characterizes the secondary or detrital laterite. It is therefore presumable that the lumps of ore are innate, and that the manganese is an integral component of the laterite in this position. The ore in the little pits is at a higher level than in the well, which is still in laterite at the water level, 45 feet from the surface, and where the ore seems to occur at any level. It is, I think, reasonable to conjecture some local source for such an unusual ingredient in so wide spread a rock as the laterite; but the underlying rocks are greatly concealed by the laterite itself, or by alluvium, and no vein of this mineral may be found in the

few exposed outcrops: manganiferous iron ore is, however, known to occur in these rocks, more to the north at Mogála and Jauli.

"Although the nature of the deposit is thus more or less obscure, I see no reason to doubt that a large supply of this ore may be depended on at Gosalpur."

The ore is dark steel gray, finely crystalline, pyrolusite, mixed with a varying proportion of psilomelane. Some lumps are almost free from the latter mineral, others contain a considerable amount; but on the whole the psilomelane is very subordinate to the pyrolusite. The exterior of the lumps, and the surfaces of most of the internal cavities are more or less coated by oxide of iron.

A carefully selected average sample of the ore yielded on analysis—

{ Manganese calculated at protosessquioxide	...	...	75.86
{ Oxygen	...	...	9.96
Iron, sesquioxide (with trace of alumina)	...	...	4.53
Baryta	...	...	3.55
Phosphoric acid	...	...	.28
Insoluble in hydrochloric acid	...	...	2.74
Combined water	...	...	2.41
Hygroscopic water	...	...	.28
			<hr/>
			99.61
			<hr/>

The ore contains 54.66 per cent of manganese, and 3.17 of iron, with .28 of phosphoric acid and no sulphuric acid. It contains 15.26 per cent of available oxygen = 83.00 per cent of peroxide; as an oxidizing agent, therefore, it is of high value, the average run of manganese ores met with in commerce containing only 60 to 75 per cent. The percentage of peroxide in the ore, calculating all the manganese as peroxide, would be 86.42 per cent., but the presence of some psilomelane reduces the available percentage about $3\frac{1}{2}$ per cent. The insoluble residue is chiefly, or entirely, silica. With reference to the presence of baryta, a substance so commonly met with in psilomelane, and not unfrequently in pyrolusite, it may be mentioned that baryta in the form of barite occurs in some quantity at Imlia near Sleemanabad, 20 miles north-east of Gosalpur.

A GEOLOGICAL RECONNOISSANCE FROM THE INDUS AT KUSHALGARH TO THE KURRAM AT THAL ON THE AFGHAN FRONTIER, by A. B. WYNNE, F.G.S., &c., *Geol. Surv. Ind.*

In volume X. of the Records, I gave a sketch of the distribution of the tertiary rocks in the N.-W. Punjab.¹ In that account, and in the map accompanying it, the ground immediately along the Affrīdi frontier is omitted. In order

¹ The information given regarding Upper Punjab geology, by the Geological Survey, being somewhat scattered, I may mention that the most important areas as yet examined will be found referred to, besides the above, in *Memoirs Geol. Sur.*, Vol. XI, pt. 2 (Trans-Indus Salt Region), also *Qrtly. Jnl.*, *Geol. Soc.*, Lond., Vol. XXX, p. 61, and Vol. XXXVI, p. 347; a memoir on the Salt Range, *Mems. Geol. Surv. Ind.*, Vol. XIV. On the neighbourhood of Murree, *Records*, Vol. V, pt. 1, and Vol. VII, pt. 2. On Jamú hills, *Records*, Vol. IX, pp. 49 and 155. On part of Upper Punjab, *Records*, Vol. VI, pt. 3. On Kharīan hills, *Records*, Vol. VIII, p. 48. On Sirban, *Memoirs*, Vol. IX, pt. 2.

to fill this gap, as far as possible, taking advantage this season (1879) of my camp being on the frontier, after visiting the continuation of the Salt Range beyond the Indus, I carried observations as far as Thal. Owing chiefly to circumstances connected with the present Affghan campaign this country, always more or less subject to frontier difficulties, presented others regarding scarcity of supplies, necessitating a rapid inspection of the ground.

The whole of the country immediately to the east and south is within the limits of the great fringing belt of tertiary rocks which borders, where it does not form, the outer hills of the Western Himalayan area (taking this in its extended sense to include all the most northerly Cis-Affghan mountains of the Punjab). These tertiary rocks of the neighbourhood embrace the upper and lower Siwalik sub-divisions of the newer mechanically formed beds, and also very extensively the underlying older tertiary "Murree group," and the eocene (Subáthu) limestones; the two last passing into each other by alternation, and the limestones becoming largely developed westwards in the Kohát salt field.

The whole route from Kushálgarh to Thal lies in the Subáthu zone, for 93 miles. Cis-Indus, all along the northern margin of the Ráwalpindi plateau, the country is traversed by what I have called the abnormal junction feature, forming the inner boundary of the outer tertiary zone; it is coincident with the base of the first high hills rising to the northwards; but further west, trans-Indus, though the same physical relations continue, of lofty limestone mountains, comprising various mesozoic and eocene groups, bordered to the south by inferior hills of tertiary age, this junction feature has not been examined, because the higher mountains at the base of which it should occur are all but entirely occupied by the wild Affridis, Zhúwakkis, Akhor Kheyls, Urukzais and other *Yagi*, or independent tribes, whose country is closed to Europeans by British authority, as strictly as Chinese Tibet is by the officials of that region. Discordance of one kind or another is the strongest characteristic of this junction feature, by some regarded as a line of fracture, by others as an unconformity marking a limit of deposition, traceable from the N.-W. Punjab to the Simla area of the Himalayas, possibly much further, and analogous to a very similar feature in the structure of the outer Alps. It dates from the Himalayan mountain-forming disturbance, posterior to earliest eocene times; and it is remarkable that, although some appearance of a transition from the older nummulitic limestone masses north of the line into the newer and more markedly nummulitic beds to the south has been observed, these newer beds have been but doubtfully distinguished north of the junction in the Upper Punjab. The weight of evidence, such as it is, goes to show that the upper nummulitics ranging south of the junction were, if at all, but sparingly deposited and capriciously distributed over the region to the north; nor is it at all certain that the nummulitic beds north of the junction may not be but a local development of older eocene limestones along the inner (northern) side of the tertiary zone.

Kushálgarh, where the Indus is now crossed by a bridge of boats, is the locality given for some mammalian bones and teeth, formerly miscalled the Attock fossils, which present certain differences from Siwalik forms, as pointed out by Mr. Lydekker in these Records, Vol. IX, pt. 3, Pal. Ind. Series X. 2. The

exact place whence these fossils were procured is unknown, and several efforts to rediscover it have failed.¹

The rocks of the neighbourhood are on the horizon of the lowest Siwalik or uppermost Murree beds, here quite impossible to separate by any distinctive petrological character, a difficulty increased by the scarcity of fossils of any kind. The existence of fossil timber, however, which is found in the lowest of these groups, though not always present, may indicate the rocks belonging to the older group of the two.

The ground, though open, is ridgy and rugged; the beds are highly inclined to the north or vertical, and run in directions from E. and W., to N. E.—S. W.: they include soft and harder greenish and gray sandstones with red, purple, and occasionally gray, alternating clays. For several miles westward of the Indus, its characteristic gneiss and metamorphic pebbles are thinly scattered over the country; but I was unable to find a single erratic, *i. e.*, travelled block or boulder such as are so numerous across the river about Jand, &c.

Eight miles to the northwards are hills of nummulitic, limestones of the Subáthu character, bent up in compressed folds, and associated with dark shales, red clays and gypseous masses. Sulphur and petroleum springs occur, closely connected with the upper zones of these limestones and clays, as on the right bank of the Indus, near Dandi hill station (where there are appearances of once extensive sulphur or alum works), or issuing from the solid limestone in the Ungo pass.

About the same distance still further northward, the main inner boundary of the Murree and Subáthu zones is over-slipped by the hill nummulitic limestone of Nilábgásh mountain, which rises immediately north of the abnormal junction feature, and includes amongst its beds jurassic, if not other secondary rocks.

Westward of the ground intervening between this and Kushálgarh, the country is apparently complicated, alternations of the limestones with red rocks of Murree aspect, displaying themselves largely in the southern part of the Zhúwakki Affrídí hills.

From Kushálgarh westward the general surface rises towards the commanding hill of Gurgurloṭ, the summit of a range which, with the exception of rock salt, repeats all the essential points of structure observed in the ridges of the Kohát salt field.

Approaching this hill, the purple and red rocks show much contortion, and fold round the greatly disturbed double anticlinal curvature which occupies the range, but so misshapen, crushed and twisted that the original simplicity of structure is greatly obscured. The axis of these folds run from N.-E. through S.-W. to a westerly strike. Just north of the Gumbat pass another ridge of nummulitic limestone includes, between itself and Gurgurloṭ, a set of the dark purple and red sandstone and clay beds of the Murree group, as a synclinal

¹ Bones seem to be specially uncommon among the beds of Kushálgarh, perhaps all the more reason for their occurrence in numbers in some local layer. Such a situation is said to have been found several years ago, 3 miles west of the village, in a cutting for the Kohát road, near a *búrj* or watch-tower.

fold. The very lowest of these, at their contact with the last-mentioned limestone, contain bones. Rib bones and fragments only were found, but unfortunately no teeth. The occurrence of these so low in the series shows, however, that the bone beds of the Punjab are by no means limited to the upper (or Siwalik) groups.

It is on the southern side of the Gurgurlot range, at Koteyri, that an extraordinary example of complete inversion occurs, placing the eocene limestone for a width of more than a furlong above the next newer group of sandstones and clays (see Trans Indus Salt Region, Mem., Geol. Sur., Ind., Vol. XI, pt. 2, p. 20.)

Besides the ordinary succession of the salt region tertiary beds, bands of flaggy limestone here appear in the gypsum, having the curious structure called cone-in-cone, very perfectly developed.

The general succession observed in and near the Gurgurlot range is as follows (in natural order):—

- | | | |
|----------------|---|---|
| Lower Siwalik | { | 5 Soft greenish-gray sandstones, with bones, and red clays; the sandstones sometimes conspicuously massed together. |
| Murree beds | | 4 Purple sandstones and bright red or purple clays. |
| Eocene Sabáthu | { | 3 Alveolina and other fossiliferous limestones. |
| | | 2 Red clay zones of the Salt Region to the south. |
| | | 1 Gypsum in massive beds and masses, with layers of dark flaggy limestone and dark grayish clays. |

Some of the springs on the southern side of Gurgurlot are said to be saline, more so at times than at others. The range declines to the westward, being connected by lower limestone ridges with the higher ones of the Bangásh hills. Both the latter and the low ridges mentioned expose here and there, interstratified with the limestones, clay and sandstone bands, having entirely the ordinary aspect of the Murree beds, but sometimes including coarse sandy calcareous layers enclosing nummulites, or bands of olive clay. An alternation of this kind is seen at the little pass on the Kohát road north of Lachi.

In the neighbourhood of Gumbat the low ground seems to have been eroded chiefly, if not entirely, from the sandstones and clays of this part of the lower tertiary rocks; and in every escarpment of the surrounding country, the red rocks are seen to underlie the limestone portion of the ridges. This appearance is as strongly seen as anywhere along the northern side of the Gurgurlot ranges; yet when followed eastward through the Gumbat pass, these red rocks are plainly resting upon the limestones.

Accepting this as the normal order, it would be easy notwithstanding appearances to suppose the limestone in all cases, or nearly all, the oldest rock. But further west this is found not to be the case, several alternations of the limestones and sandstones of different thicknesses taking place; so that it becomes exceedingly difficult to find the true positions of these limestones and red rocks where the sections are isolated or much contorted.

From Gumbat to Kohát the road passes for 8 miles through an open earthy or stony country of alluvial flats, terraces, and undulations exposing either the lower tertiary sandstone and clays, or limestones; the Gurgurlot range lies to the south, and the rugged hills of Zhúwakki land are approached to the north, showing long edges of limestone cropping out above the red Murree-like rocks.

Nearer to Kohát, about Billotang, low barren limestone hills are entered, showing many undulations of the beds at all angles up to vertical, and several of these again exhibit the same alternation of the limestone, sandstone and red clays. A low ridge from these hills stretches towards Kohát, in front of the lofty and highly contorted or partially scarped limestone mountains of the Affrídís, crossed by the hired pass from this country to Pesháwur.

The remainder of the distance to Kohát (15 miles from Gumbat) is through flat irrigated country; but in the ascent from the station to the pass just mentioned, dark arenaceous and rusty impure limestones, containing jurassic and cretaceous fossils, are folded amongst the dark gray nummulitic limestones of the bill type; and the line of abnormal junction traverses the country from east to west along the southern face of the Affrídí hills. Further north, within the pass, much of the gray limestone everywhere visible may be of triassic or at least mesozoic age; a sufficiently close examination to decide this was prevented by political reasons at the time I traversed the pass.

At Kohát one is close to the frontier, the much folded and contorted limestone wall of the Affrídí mountains, rising abruptly from the northern side of the Bangásh, or Kohát Towey, valley and attaining greater elevation as the mountains run westward. The station is built upon a stony rising ground, one of the many fan-like accumulations of subaerial detritus at the mouths of the mountainous valleys of the Upper Punjab¹. The situation, the vicinity of a mass of limestone mountains, and the presence of coarse stony superficial deposits, are all favorable towards the existence of the remarkable springs which occur here; a large one, over which a musjíd has been built, sends forth a perpetual great stream sufficient to turn the wheels of several mills, and to water the whole station. Looking towards the Bangásh valley, famous for its fruit trees, its limpid streams, and the cutting cold wind which blows down it on winter mornings, the high mountains lie to the north, and a long ridge, also of limestone, terminating eastward in considerable rugged eminences, closes it in on the south. This southern ridge is of fossiliferous upper nummulitic limestone, overlying a thick band of such gray sandstones and red clays as are common in the Murree group, the whole dipping rather steeply to the south. The only spot at which the northern limestones could be inspected was near a group of ruins, some 4 miles from the station, perched nearly on the top of a minor spur. The limestones here were found to contain dark and rusty beds distinguishable even from the road, amongst which *Belemnites* and fragments of other cretaceous *Cephalopoda* (as determined by Dr. Waagen) were observed. The beds as usual appeared to be folded, but from a distance the whole face of the mountains presents sufficient of a northerly dip to give them a decidedly scarped appearance. Here also were found the ordinary features of the line of abnormal junction: on one side nummulitic limestones interstratified with red beds of the older tertiary aspect, and on the other, different hard limestones, including bands containing jurassic

¹ Finely displayed, I am told, along the upper waters of the Kurram river in Afghanistan, as seen from the Peiwar Kotul route.

and cretaceous fossils, the beds dipping diversely and presenting the appearance of fractured displacement.

The valley is narrow, scarcely a mile in width, the frontier line sometimes not more than half that distance from the road, and the surface is formed of a drab saline clay soil or alluvium, apt to harden at first on drying, then to pulverise into fine dust, and to form rapidly deep fluid mud on the access of rain. Near the village of Kuz-Usturzai,¹ the main stream is joined by another from the valley of Samilzai and Murrai, which re-enters the mass of the mountains to the northward for some 8 or 10 miles, and might therefore be likely to expose something of their geological relation. As is not unusual along the frontier, this recess containing some cultivable ground, is included within the British boundary, the "red line" leaving the mountains outside; still it was considered expedient that I should not enter the valley without an increased guard and special arrangements, which the pressure of circumstances precluded. So far as could be seen, the ground within it was traversed by low limestone ridges, partly continuous with, and partly repeating, the features of the adjacent part of the main valley, where nothing except eocene beds were recognized. On the north-eastern and northern sides of this Murrai valley, the lofty limestone escarpment from the neighbourhood of Kohát was observed to sweep along, broken by ravines and plateau-like summits, towards Khuyakkai Sir, culminating some miles to the westward at the tabular summits of Mazzeoghar and Dupah Sir,—the latter over 8,000 feet in height, faced to the south by stupendous cliffs, and overlooking the high valley of Tirah to the north.

In these cliffs strong zones of gray limestone, alternating with much softer thick bands, probably of shale, could be seen dipping at angles of 30° and 40° in northerly directions, the dip becoming more marked and steeper in the same direction, away to the westward. The stream coming from these mountains brings down pebbles chiefly of dark gray limestone in which fossils are concealed or absent, but the rock looks and smells like the hill variety of the nummulitic limestone; there are also a few of light-coloured fossiliferous nummulitic limestone, others of a greenish semi-oolitic limestone, containing parts of bivalve shells with strongly marked umbones and many large blocks of hard white quartzite sandstone.

The road to Hangu rises from the alluvium of this stream on to flat-topped *Karewah* hills, formed of horizontal boulder conglomerates, from 40 to 100 feet thick, beneath which are vertical grayish dull sandstones and bright red clays. These last are seen again edging the bases of long low nummulitic ridges to the northward, which dip into the valley in various northerly directions. It here becomes evident that the Hangu valley is excavated upon the softer much disturbed red clays and sandstones underlying and interstratified with thick zones of the *Alveolina* and other upper nummulitic limestone, the whole arrangement being not unlike that of the Subáthu beds in many places along the north of the Ráwalpindi plateau, but on a much larger scale. Deep excavation in the valley beds and the stony hills they form continue to the camping ground of Sherkot, 12 miles from Kohát, and there is nothing in the structure of the ground within British territory here to mark the westerly continuation of the discordance

¹ Commonly called "Sthoorzee" by the natives.

between the nummulitic beds of the vicinity and the limestones of the mountains to the north.

In the next march, to Ibrahimzai (8 miles), another stream from the northern hills, having a long easterly course from behind the Samána ridge, is crossed at Raiss; the boulders in the stream being of similar kinds to those previously mentioned. The valley here becomes much more confined and hilly, and at the fifteenth mile from Kohát is obliquely crossed by the ridge which has hitherto bordered it on the south, the river finding its way through a deep gap called Khwajakhkezal. In the ascent to where the road is led through this pass, on the northern bank of the stream, as in some hills to the eastward, the more solid limestone of the ridges is seen to overlie compact lumpy gray or drab Alveolina limestone, which rests upon strong gray sandstones immediately overlying thick red clays; the whole folded into an anticlinal and synclinal curvature. From the top of the pass to its western opening, an ascending series with a dip of 50° or 60° is exposed, thus—

Upper nummulitic.	{	Red clays; remains of a band several feet thick.	
		Strong nummulitic limestones, overlying	... 234'
		Greenish shaly and softer beds, concealed by talus	... 219'
		Red clays.	Obscured.
		Thick alternations of strong bedded and shaly lime- stone and greenish shales; layers of the lime- stone crowded with fossils	... 258'
		Grayish and purplish sandstones with red clays	... over 100'
		<hr/>	
		811'	

Westward of the pass the valley again slightly opens, and on its south side higher beds of the limestone, overlying red clays, &c., with a southerly dip, form a ridge extending nearly to Ibrahimzai. About this village all the much disturbed high-cliff-forming limestone ridges strike westward obliquely across the valley to the flanks of the Samána ridge.

From Ibrahimzai to Mirkhweli (the hill sanitarium for Kohát, having an elevation of 4,700 feet), 5 miles to the south-east, many alternations of the limestones, clays and sandstones are exposed, at first nearly vertical, then forming a wide synclinal basin, over the central, east and west, axis of which is the little station of Mirkhweli. All these beds are higher in the series than those of the succession given above, and have an estimated thickness of fully 4,000 feet.

The northern slopes and precipices of these hills are much concealed by a jungle, often densely luxuriant, of *Kao*, *Fullái*, *Mazzurra* (dwarf palm), *Sunbetta* and other bushes, sometimes attaining the growth of trees, and supporting vines. Hence the thicknesses of the zones in detail are not readily distinguishable, though they may be roughly stated at from two to four hundred feet. The following series was here made out (natural order):—

FIG. 1 (see Map).

14. Small limestone cap on summit of Mirkhweli.
13. Purple clay zone, under the Deputy Commissioner's house.
12. Thick capping of gray Alveolina limestone, forming the general hill top.
11. Red and purple earthy and sandstone rocks of the aspect of Murree beds.

Numerous fragments of a gray (green-weathering), coarse calcareous sandstone, conglomeratic with fragments of quartzite and white hornstone, are scattered over the slopes of Mirkhweli formed by this zone; its presence *in situ* here can scarcely be doubted.

- 10 Very thick zone of gray Alveolina limestone, defining the basin and forming the summit of Spirkhwet hill.
9. Red clays.
8. Very thick band of olive clays.
7. Dark ferruginous and greenish gray conglomerate, pebbles, white chert and quartzite.
6. Compact nummulitic and Alveolina limestone.
5. Red clay, overlying bands of dull sandstone.
4. Thick olive clays or shales.
3. Red clays.
2. Strong ridge of gray limestone.
1. Red clays and dull-coloured sandstones, a thick band, overlying limestones of similar kind as above-noted.

Beneath these last mentioned limestones are the uppermost beds of the succession previously given, so that this part of the Sabáthu group appears to have a thickness of 5,000 to 5,500 feet, roughly estimated.

From the summit of Mirkhweli, looking northwards, a fine view is obtained of the lofty limestone mountains, with the lower Samána ridge in front, forming a marked anticlinal curve, its southern side being sheeted with inclined curving beds of bare rock dotted with scattered jungle, while the ranges behind continue the northern slope of the curve. The alternation of gray limestone and thick softer zones is very visible, but nothing redder than the colour of the withered *Bubber* grass could be seen by the aid of a field glass. These mountains in Urakzai are so high, that even from this elevation (2,000 feet by aneroid above Ibrahimzai, and 4,700 feet above the sea), but little of the Safed Koh, away towards its peak of Sikaram, could be seen.

In the opposite direction Mirkhweli dominates all the numerous limestone ridges and valleys occupied by the red rocks, &c., of the Kohát salt field.

From Ibrahimzai to Hangu the valley narrows and seems blocked by overlapping profiles of limestone ridges, one of these, north of the road, again showing distinctly a thick intercalated band of the red rocks between two limestone zones. At Hangu the latter is dark, containing but few fossils, and dips strongly to the north-east. Here a small valley running northwards reaches the Samána anticlinal beyond the frontier. By sending a messenger into this forbidden ground, I obtained specimens of dun lithographic textured limestone, some without fossils, but one full of *Alveolinæ* which was stated to have been taken from the southerly sloping beds of the ridge. Others were of white sandstone, rusty externally, the position of which was shown as a band along the foot of this Samána ridge. This white sandstone is identical with the blocks in the streams near Sherkot.

The hills south of the valley at this place are rugged, jungly, and grassy limestone masses, evidently continuing the undulation of the Mirkhweli section. At this part of the valley the soil has changed colour to darker brown and black tints, the cause of which is not very evident.

From Hangu to Togh, 34 miles from Kohát, the valley opens out considerably, the Samána ridge trending to the N. W., and long terrace-like mounds or fans are seen along its north side, similar to those observed in the Teri valley to the south (Mem. Geol. Sur., Vol. XI, p. 109). The frontage of the northern hills still shows the anticlinal slope of the Samána ridge, overtopped by the scarped edges of the beds in the mountains beyond. South and south-westward the same features continue as were noticed from Hangu; but a depression in the crest of the nearest range allows other parallel ridges with long horizontal outcrops of limestone to be seen beyond.

From Togh to Suruzai, 11 miles, the valley becomes still wider; its crest is passed at Kai, and the Zwymukht valley joining it from the north-west, the superficial waters unite to form the Shakkalli stream, which falls into the Kurram below Thal.

Most of the ground is covered with low accacia and Mazzurra jungle, and two lofty clusters of limestone mountains are seen to the westward, one the Dano hills over Tarawari and Darsamand, the other the Kadimuk group immediately north of Thal camp.

Near Togh, at the village of Bar, a mass of green clays with harder calcareous mudstone layers shows itself, dipping at 60° beneath the limestone of the southern side of the valley; it appears to be more than 200 feet thick, and has white *kallar* efflorescence, but no fossils could be found in it, its aspect is not unlike the *Sheor Kowra* clays of the Kohát salt field. This band seems to follow the course of the Shakkalli stream the whole way to and below Thal.

Near Kai there are long flat-topped, slightly hanging, terrace-like detrital hills, and on the "divide" between the Shakkalli and Kohát Towis there are some outcrops of dark green coarse gravelly and fine olive quartzose calcareous grits; these beds weather black, and the gravelly ones contain little fragments of limestone, mostly angular. Over these are green clays, similar to those at Bar, with purple bands and hard sandstone layers; the group is evidently much folded, on east and west lines. It is not improbable that the large valley here has been mainly excavated from these rocks, which possess more or less of a Subáthu aspect, but yielded no fossils except some broad striated plant impressions.

North of this the Samána ridge appears to inosculate with the higher limestone hills, the scarps of which, running west by north for the summit of Zawaghar (9,380 feet), still shew prominently two or more broad zones of shales, or other soft beds, between the harder ones of limestone, the dip having now come round to north-by-east.

To the west the Dano and Kadimuk mountains both show great anticlinal axes to the south, with strong northerly dips at 45° , and inner folds along the lesser elevations, uniting them with the Urakzai mountains northwards. To the south the rolling nummulitic limestone hills still shut in the valley extending nearly as far as Gandior, 54 miles from Kohát.

In the streams from the northward between Kai and Togh, I found numbers of light-coloured sandstone blocks, some of dark green quartzite, and many dark gray limestone pebbles, some of which contain shell fragments. Fragments of a dark gray limestone, weathering deeply to a brown colour, contain fragments

of *Rhynchonnella* with smaller bivalves, and a dark conglomeratic semi-oolitic calcareous grit, with white quartz in scattered grains, was found to enclose *Belemnites*. This stream comes from the highest part of the Samána ridge, where there is at least this evidence of the occurrence of the mesozoic rocks. The beds of streams further west towards Suruzai and Doaba are largely filled with gray shale detritus; one coming from Darsamand also contains dark sandstone fragments enclosing *Belemnites*, and the soil is frequently dark coloured or blackish recalling the cotton soil of the Deccan.

From Suruzai to Gandior the character of the country is quite the same as just now described. Crossing the Mazzurra-covered plain from Gandior to the Darsamand mountain, near the base of the latter, greatly disturbed, dark rugged limestone with small nummulites and the little *Rotalina* characteristic of the eocene hill limestones are first seen. Some of the beds have a conglomeratic structure enclosing limestone lumps. A band of sandy limestone also appears, and then green quartzose grits, weathering to a black metallic colour. Beyond these is a strong rib of thick and thin-bedded compact gray limestone without fossils, dipping at high angles northwards and underlying a band of dark greenish and rusty olive or whitish hard coarse silicious sandstone, the dip of which is 50° . Similar sandstone and hard olive shaly beds occur on the further side of a hollow as if faulted against massive blue limestone, with a southerly dip at right angles. Sheets of this stretch up the mountain side forming the southern slopes of the anticlinal curve before mentioned. No fossils were found *in situ* in these limestones, but fragments from the hill contain *Rhynchonnella*, oysters and *Chemnitzia*-like spirals, and have a semi-oolitic structure.

Here all similarity to the nummulitic limestone has vanished, and a fault evidently separates the latter from the rocks of the hills. Moreover, these at the point struck must belong to a middle portion of the hill section, for the axis of the anticlinal bending downwards brings in higher beds to the eastward, likewise checked against the low outer rib of limestones, &c., having a northerly dip.

The fault here may be the great fractured junction feature of the eastern Upper Punjab section, but a hasty glance was all that could be obtained at the ground, the frontier lines here, as is often the case, being rather hypothetical. Between Gandior and Thal (63 miles from Kohát) this long valley, through which a main route from Afghanistan has lain since the time of Baber, becomes again narrow, though joined from the north by the Singrobaglen. The mountain masses of Dano and Kadimuk shut out the more distant ones to the north in a great measure, and the southern side of the valley is no longer formed of limestone, but of almost horizontally bedded sandstone and clays, partly of the Murree group, and partly of Lower Siwalik aspect, the continuation of those occupying the Dallan valley. (Mem. Geol. Sur., Vol. XI, p. 101.)

At the southern bank of the river, not far from Gandior thannah, is a mass of limestone conglomerate with all the appearance of the usual valley beds, in a consolidated state, but it dips at 60° to the north-west, resting on or against greenish and purple clays, which come out from beneath the nummulitic limestones. The position of this conglomerate may perhaps be accounted for by supposing an old consolidated terrace to have been undercut by the river, and

to have subsided into this sloping attitude by its own weight. If not, the occurrence is remarkable.

The walled village and the camp at Thal are situated at the confluence of the Singroba stream with the river Kurram, and upon coarse detrital river accumulations of the local rocks. The elevation is supposed to be about, or somewhat over, 2,000 feet. Within a mile of the camp to the north, the high mountain of Kadimuk shows a short east and west anticlinal axis, around which the strong-bedded limestones form an elliptical quaquaversal dome.

Favoured by Colonel Gordon, commanding at Thal, with an extra guard, I was enabled to visit the lower part of this mountain. On the way there an exterior group of hills was crossed, composed of contorted, vertical and much disturbed, hard olive and gray quartzose sandstones, covered with a dark metallic lustrous film, and green, gray or purple clays, some of which are exceedingly fine and hard, with a splintery structure. Subordinate beds and bands of marly limestone also occur. Some of the latter contain well-preserved corals of two or three species, and in one bed of the externally dark-coloured sandstone I observed a few casts of small echinoderms.

Among the lowest beds of this exterior (? lower Sabáthu) group are unequally coarse sandstones, enclosing fragments and large blocks and blotches of limestone. Nearly in the same strike I also found a thick bed of limestone conglomerate, apparently reconstructed from such limestones as those of Kadimuk. The base is sandy, and lying on the rock, as if weathered out of this, a fragment of a *Belemnite* was picked up. Notwithstanding the interstratification, there is in consequence of the occurrence of this bed some appearance of a break low down in the group; but the relations of this to the rock of Kadimuk are those much more of faulted discordance than of unconformity. The whole outer group, in spite of the faulted appearance, sweeps round the axial western dip of the high mountain, and for some distance from the river strikes up the left bank of the Kurram.

At the southern base of the mountain a thin band of the dark-weathered sandstones, &c., separates a considerable mass of gray limestone from the Kadimuk anticlinal. This limestone has an uneven texture, showing small black specks like minute organisms, with a few narrow spines. Such limestone is not uncommon in the lower hill-nummulitics of the region north of Ráwalpindi plateau.

In the strong limestones of the mountain I found no fossils *in situ*, but fallen fragments contained anneloid tracks, oysters, bryozoa, or small corallines and corals, many small gastropoda, some like *Nerinea*, and a few sections of impacted little bivalves, the aspect of the whole being that of older limestones than any of the eocene ones I am acquainted with.

One of the officers of the Kurram force (Mr. Macleod, 29th Punjab Infantry) informs me that some time ago near the summit of Kadimuk, beneath a limestone cliff, he found several ammonites lying on the surface of a softer band. I was unfortunately not able to procure any specimens of these, even through an inhabitant of Thal who knew where they are; for it appeared that part of the mountain was occupied by a wandering party of Ghilzais with whom the people of Thal were at feud.

Immediately across the Kurram, on the Afghan side opposite to Thal, is the very rugged hill of Bakkarkanch (flint-stone), entirely different in appearance from any of the neighbouring ones. It is chiefly formed of masses of hardened and altered brecciated beds, some being altered limestone or a silicious rock full of angular fragments of hornstone or flint,¹ usually mottled or banded with reddish or dark purple and gray tints. Others enclose also angular fragments of white earthy limestone, as if the whole had once formed flaggy beds; but the fragments now lie at all angles in the rock. Between these beds are purple, flaggy and gray or greenish shaly bands of Subáthu aspect, layers of a ferruginous red lateritic rock, and some of very hard thin-bedded limestone without fossils. The beds are broken into disconnected masses, and the cause of their alteration is not far to seek, for everywhere through the hill are numerous intrusions of hard, dark or decomposed, variously coarse, crystalline, syenitic and compact trap, weathering down so as to be less prominent than the silicious altered rocks. Looking from one of the summits towards the westward, a large space among lower hills was seen to be occupied by cores of the dark crystalline trap, the chief sources of which may be in this direction.

Besides the dark solid traps there are also what seem to be masses of agglomerate of trappean fragments, and fine-grained tufaceous traps, alternating in beds or layers. It was not found possible to recognise such an association of these lava-like rocks with the altered ones as would establish contemporaneity; but the entire assemblage has the mixed appearance one would expect to find near the core of a denuded volcanic vent.

Just beneath and in the under surface of one of the brecciated bands near the top of the ridge, old excavations were shown, made along the outcrop in order to extract a dark, gray and black heavy mineral which soils the fingers and marks paper. It occurs in but small quantity and seems to be a mixture of graphite with something else disseminated in the breccia; it is used by the natives as "kohl," and they call it of course *súrma*.² (I have not yet had time to examine it closely).

This is the first instance in which I have met with igneous rocks among any of the mesozoic or tertiary groups of the Punjab. The locality is fairly within the region of the Subáthu beds, and these trapps may be but an outlying portion of a larger igneous area to the westward towards Khost,³ in which direction, as well as up the course of the Kurram as far as can be seen, the mountains present a softness of outline and a generally bare or withered-grass-covered aspect, entirely unlike that of the hills around on any other side.

Chaperoned by a couple of tame armed Waziris, in addition to the guard, I visited the scarped outcrop of their hills south of Thal. On the way thither, a low ridge between the Singroba and Shakkalli streams was found to consist

¹ Much used by the *Yagi* tribes for gun flints.

² This is perhaps the mineral mentioned as antimony occurring at Punjali-i-Shah Kurram river, by Agha Abbas, in Jour. As. Soc. Bengal. vol. XII, p. 595.

³ I have seen specimens of asbestos from two miles west of Segai Kángah Khost, where it is so plentiful the people are said to make it into ropes; the locality is stated to be two long days' journey from Thal into Afghanistan.

of the same kind of hard, dark-weathered sandstones and olive and purple shales as occur between Thal and Kadimuk. The beds are vertical and folded, striking nearly N. N. E., and some of the sandstone bands contain badly preserved shells of large oysters, others those of a long and narrow but smaller form. South of the Shakkalli river is a mass of greenish gray clay coasting round the escarpment, extending down the Kurram, and very probably the same zone as is seen at intervals eastward as far as Togh. Resting upon this clay with a southerly dip, there is a band of some 100 or 150 feet of dark and lighter-coloured, mostly thin-bedded, compact, *Alveolina* limestone, immediately succeeded by a thin layer of calcareous concretionary pseudo-conglomerate, over which come the usual bright red clays and gray sandstones of the Murree group, the latter here sometimes enclosing small pebbles. Climbing to the top of the scarp, these and similar beds are seen to undulate over the country towards Dallan. Southwards they form large horizontally stratified elevations, amongst which a scarped hill at a distance, the scarp doubtless formed by a somewhat bent and twisted zone of nummulitic limestone, is the western termination of the Ragotungi ridge of the Kohát salt field, where that ridge passes into Waziri land. Still further off to the south is the rugged outline of a high ridge in the upper Siwalik sandstone and conglomerate basin north of Banu.¹

Near the edge of the scarp, not so much as 200 feet stratigraphically above the nummulitic *Alveolina* limestone, I found several fragments of large mammalian bones in a coarse pseudo-conglomeratic layer, but could find no teeth. One narrow bone, broken into three fragments, seemed to show the tubular structure of those belonging to birds. I have preserved the specimen, though a bad one.

This was all that I could ascertain of the local geology of Thal: the high mountains beyond the Kurram were too far off to form a close guess as to their composition. In the river and in the terrace above it, the travelled boulders and pebbles, loose or cemented into conglomerate, present a great variety of rocks, amongst which the only ones I could identify with those of the Indus deposits were a dark fine-grained syenitic gneiss and a well-known variety of white quartzite covered with conchoidal markings like gastropod sections, which occurs *in situ* among the Tanol rocks of Hazára. Others include varieties of gneiss, coarse and fine, micaceous schists, altered earthy and silicious rocks, red jasper, white and brown quartzite, purple quartzite, gray sandstone, gray and purple ferruginous limestone, dark hornblendic trap, white eurite, white semi-crystalline marble, red quartzite, many limestones, but none, that I observed, of slate. These may all be found hereafter on the flanks of the Sufed Koh.

Conclusion.—The route from Kushálgarh to Thal shows a considerable change in the upper nummulitic zone compared with its eastern sections as far as the river Jhelum. Near Murree this zone has an apparent thickness of some 6,000 feet, and is most largely composed of clays and sandstones frequently of red or reddish colours with subordinate bands of coarse fossiliferous (num-

¹ A nummulitic limestone patch in Waziri land, north of Banu, shown on the sketch map, Records, Vol. X, p 107, has been a good deal misplaced to the westward of its real situation.

mulitic) sandstone, or of marly or pure limestone, and one prominent dark limestone band 700 feet thick.

In the Ráwalpindi plateau the zone is greatly disturbed, has apparently a less thickness, up to 1,500 or 2,000 feet, and comprises a few alternations of highly fossiliferous, marly and other nummulitic limestones, with red, purple and olive clays, &c.

Gypsum and petroleum occur along this part of the zone, chiefly in the lower ground, the former in considerable quantity; gypsum also is met with in red rocks of somewhat Subáthu aspect, their relations obscured by disturbance, among the Mochipuri mountains north of Murree, at Dungagali, &c.

In Bangásh on the road to Thal and southwards, these Subáthu eocene rocks occupy a large area, one part of their section alone giving an estimated thickness of more than an English mile, to which large additions should be made for the total bulk of the group, not less perhaps than 7,000 or 8,000 feet. The limestones here occur in thick zones of from one to over 300 feet, becoming more numerous northwards in the Mirkhweli region, and largely made up of beds containing *Alveolina* almost exclusively. Interstratified with these are thicker zones of rocks exactly resembling Murree beds, but including also many bands of olive clay. The gypsum of the group appears here in the salt field, and on its borders, but much more largely developed than to the east.

It would seem that the zone is changing again to the westward, the limestones disappearing in a great measure, and a mass of unusually hard sandstones with marine fossils and very thick greenish or gray and some purple clays forming a prominent part of the group in the neighbourhood of Thal.

A possible break at the top of the Salt-range nummulitic limestone has been suggested by Mr. Medlicott,¹ partly from the occurrence of a band of limestone conglomerate at the base of the overlying series. The presence of this detrital rock is not accompanied by any visible stratigraphic discordance, and in the section on the flank of Kadimuk north of Thal, we have a band of limestone conglomerate interstratified with the local lower part of the Subáthu beds. This occurrence is perhaps worth noting in connexion with the supposed break, with the abnormal northern junction of this Subáthu zone and the hill limestones, with the appearance of a transition across this break at Clifton (Murree), and with the absence of any unquestionable representative of the Subáthu zone north of the line of abnormal junction, so far as is yet known, nearer than the distant deposits on the Upper Indus, if even there.

Nothing has been found in this country antagonistic to views I have previously expressed regarding the nummulitic rocks of the Punjab (Records, Vol. X, p. 109, etc.), particularly as to the position of the Subáthu eocene beds above the mass of the eocene hill limestones². Still some approach to the eocene hill limestone character among these rocks has been observed in scarcity of fossils and darkness of colour. Perhaps no feature is more prominent in the structural geology of the Punjab than the liability of its rocks to horizontal (lateral) varia-

¹ Memoirs, Vol. III, Pt. 2, p. 91, and Records, Vol IX, p. 57.

² See note 2, p. 130.

tion in thickness and character,—an observation quite borne out by this western part of the upper nummulitic group.

The occurrence of igneous, possibly volcanic, rocks in the Subáthu zone at Thal, should any of them prove contemporaneous, and should they be largely developed to the west, may introduce an entirely new feature, complicating the relations of this Subáthu group to the neighbouring tertiary or older rocks of that part of Afghanistan.

It may be possible that some of the Mirkhweli Subáthu limestones extend into the Urakzai mountains, the strike of parts of these lying in the same general direction as that of the Bangásh hills; but near Hangu, where the latter most nearly approach the former, a sudden difference of both dip and strike between the two sets of rocks was suggestive of a fault; nor were the interstratified red rocks of the Mirkhweli sections seen anywhere in the much-exposed Urakzai escarpments. Further west at Thal and Darsamand, where spurs from the northern mountains were reached, indications of fracture dividing the Subáthu zone from limestones of secondary age were found in both cases.

Of the age of the rocks forming these northern mountains, it has only been possible to collect some evidence of the presence of mesozoic rocks. The great height and bulk of the mountains, as well as the conspicuous northerly inclinations of their strata, together with their being so largely composed of limestones, leave ample room for the occurrence of all the eocene and mesozoic groups of the northern Punjab ranges, and space to spare for palæozoic ones besides; but in none of the streams coming from them, did I observe any fragments or fossils proving the existence of palæozoic rocks among these mountains.

The very low horizon at which bones, presumably mammalian, were found south of Thal is not incompatible with the distribution of bone beds elsewhere in the Upper Punjab, these occurring even among the nummulitic rocks themselves. The circumstance may also be connected with the gradual disappearance in a southerly and westerly direction of nearly the whole of the great group of the lower tertiary mechanically formed beds, the absence of which is a marked feature in the westerly extension of the Salt Range, trans-Indus.

FURTHER NOTES ON THE GEOLOGY OF THE UPPER PUNJAB, by A. B. WYNNE, F.G.S.,
Geological Survey of India.

(*Supplementary to those in Records, Geological Survey, vol. X.*)

Description of the ground.—The rugged district of Hazára stretches far into the regions of the Western Himalaya between the rivers Indus and Kishenganga, and embraces the native hill states of Amb and Kaghán as well as the portion directly under British rule. Its mountains, being parts of the greater ranges, present a somewhat complex assemblage of lofty spurs, rather than distinctly individual chains.

The long glen of Kaghán curves to the eastward-by-north between great snowy ridges. Its stream is the Nainsúk, or Kunhar, river, which enters the

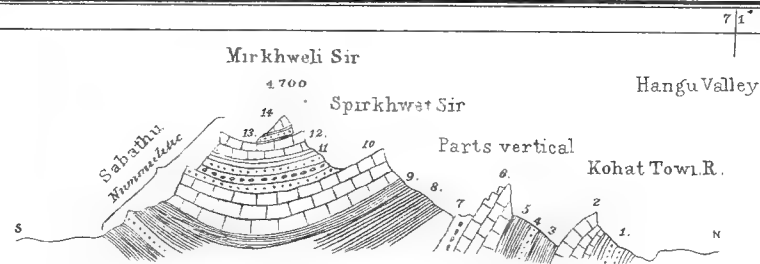


Fig. 1. Sketch section over Mirkhewi Sir; numbers refer to succession in text.

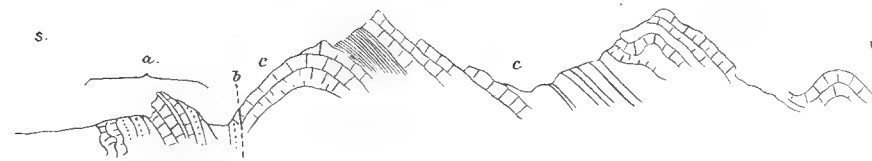
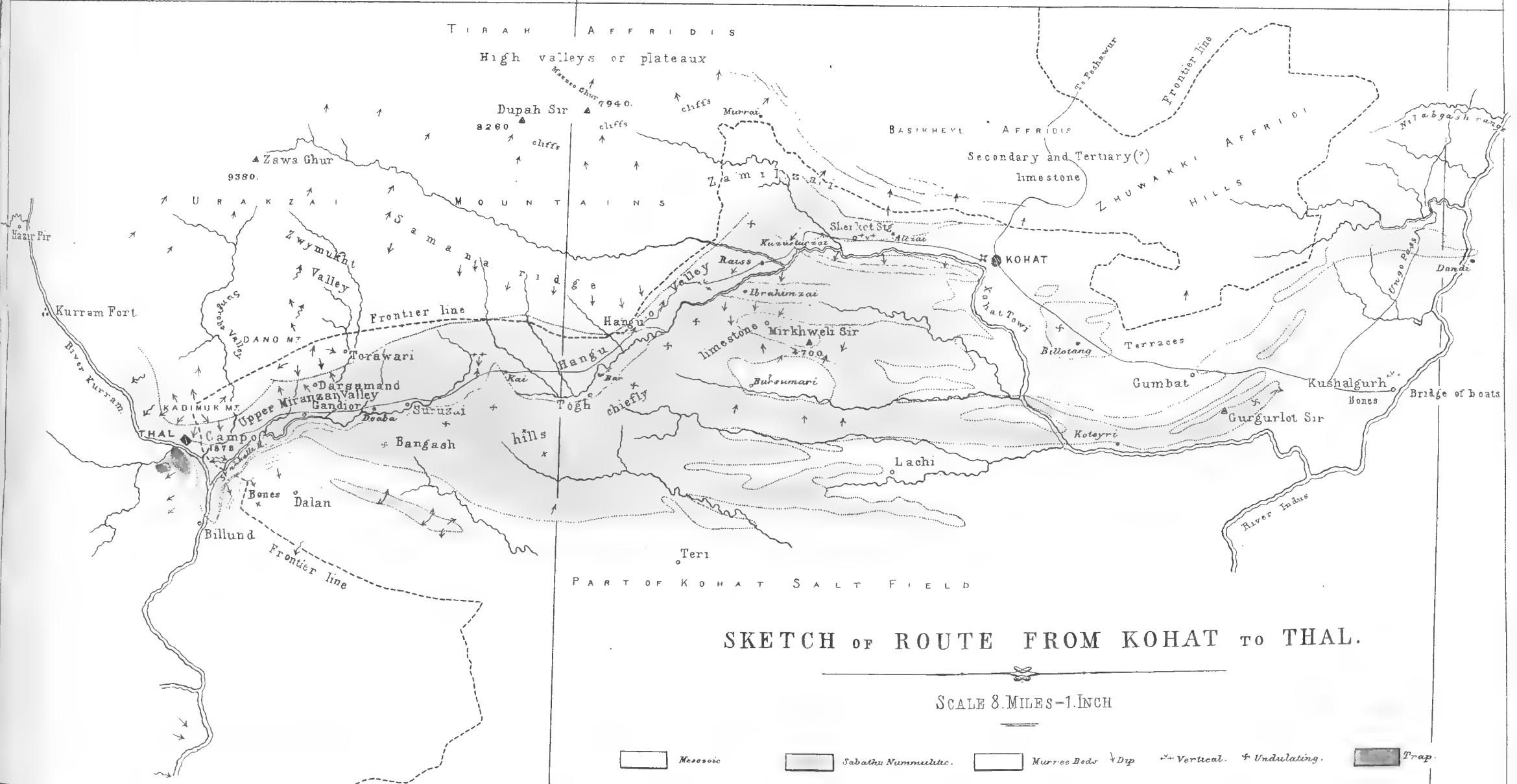
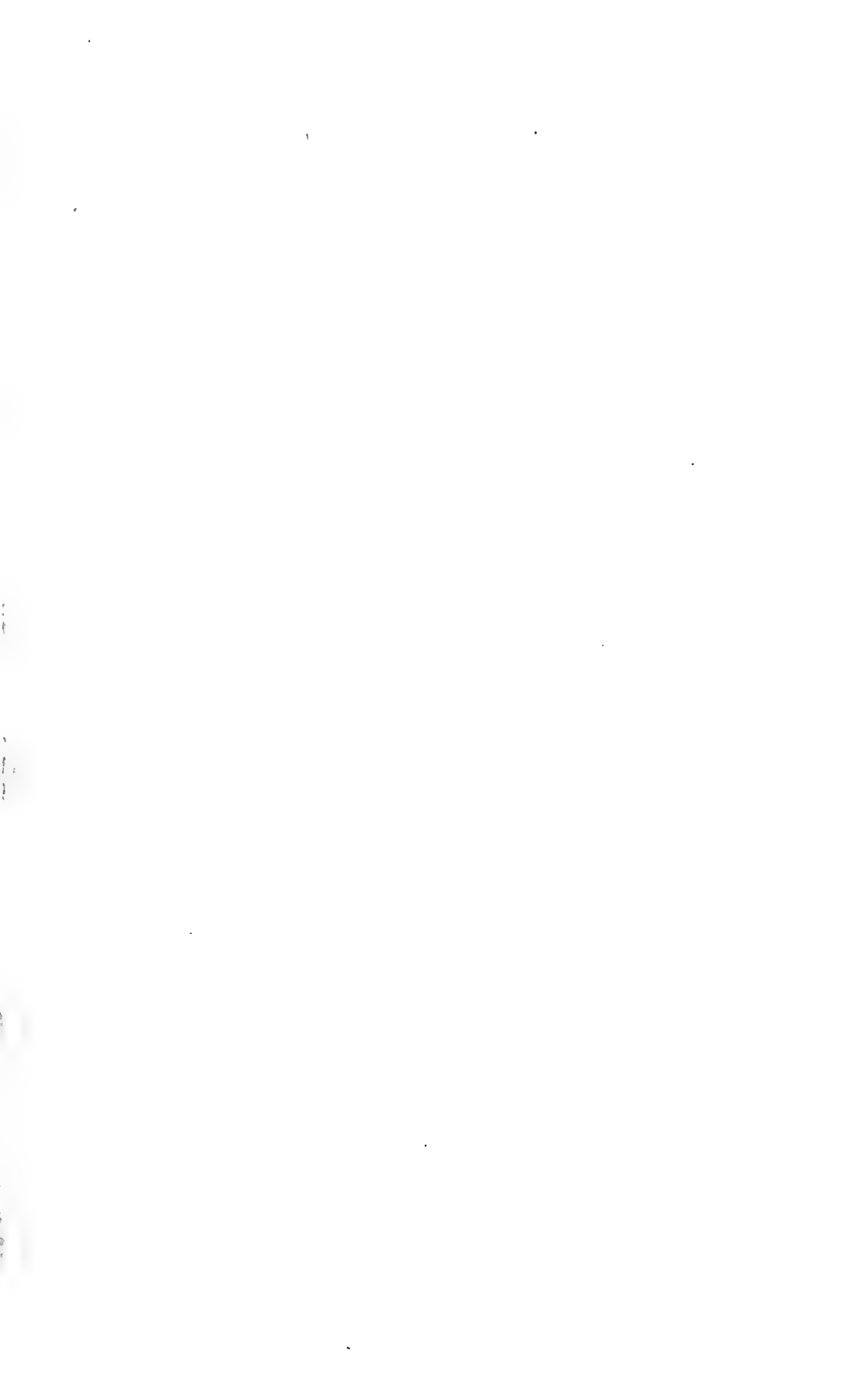


Fig. 2. Diagram of Darsamand Hills.

a. Nummulitic beds b. Fault c. Mesozoic limestone and shales.





Jhelum below Muzaffarabad. Between the north-western watershed of the Kaghán valley and another great mountain spur from the northwards, the upper waters of the local river Sirun find their way southwards towards the Indus through the valley of Bogurmang. On the east of this valley is the lofty truncated peak called Músa-ka Masala (the praying carpet of Moses), 13,378', situated in the border country of the hill-men nominally within our frontier; and on the west are high elevations called Palleja Behisht (Heaven) and Shaitán-ka-gali (the devil's neck or pass). Further west the Black mountains (scene of late frontier warfare) rise, on this side of the unknown, or at least unmapped, portion of the upper Indus channel.

One march westward of the lower Nainsúk, at a much greater elevation surrounded by still higher mountains, is the flat lake-like plain on the course of the river Sirun forming the detritus-filled valley of Pakli.

Between the Pakli valley and the Indus rises the mass of mountains in the state of Amb, culminating at Bahingra in a height of 8,608 feet above sea level.

A broad cluster of hills having elevations of four, five, and six thousand feet spreads from the Sirun to the valley of the Dore; and from near the junction of these two streams the most isolated ridge in the whole country, that of Gandgarh, trends in a south-westerly direction, rising to an elevation of 4,137 feet between the Hazára plain and the river Indus.

Again, occupying the southern side of the district is another, broader, lofty tract, presenting endless alternations of confluent ridge and valley, with a marked north-east south-west strike. This elevated tract rises from the Nainsúk torrent, near Ghari Habibula, and with altitudes of 8,000 and 9,000 feet overlooks that river and the Jhelum; then, passing between the stations of Murree and Abbottabad, it gradually becomes less elevated, though still presenting high summits and long south-westerly valleys, till it leaves the district as a part of the Márgalla range, near the grand trunk road from Ráwalpindi to Hasan Abdál.

The Indus valley is a deep defile amongst the mountains, where, coming from the north, the river first bounds this district, then passing Derband, Amb, and Sittána, its valley expands to a width of about two miles at Torbela, a few miles below which place it opens out upon the plains of Chuch and Yusufzai.

All over southern Hazára the more or less north-east south-west run of the valleys, streams, and ridges coincides generally with the strike of the rocks. In central Hazára, disturbance of the strike would appear to have produced a less regular structure of the ground as to depressions. In the Gandgarh range, this ridge is itself a strike-feature, and the mountain torrents cross the bedding of the rocks; while in northern Hazára, in Agror, Bogurmang and the lower part of the Kaghán valley, the northerly and north-westerly run of the rocks, resulting in many marked features of the ground, approximates more to the general Himalayan bearing eastward of the river Jhelum, than to the abruptly deflected south-westerly strike of the rocks westward of the same river.

Geological structure.—I have already given some account of the outer Himalayan series in Hazára (Rec. Geol. Surv. Ind., vol. X, part 3); but now that it is to be noticed at more length, it will be well to subjoin a short

tabular list of these Hazára groups, placed as far as possible in their natural order of stratigraphical succession as follows:—

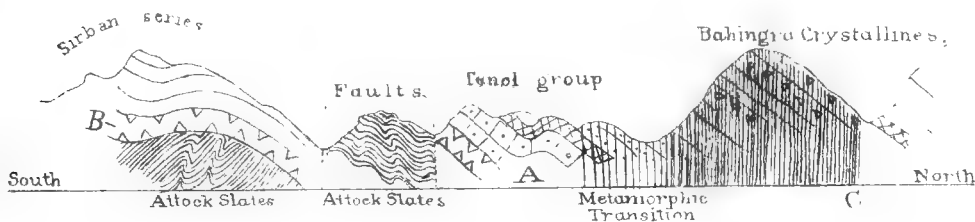
CAINO- ZOIC.	PLEISTOCENE	12	Northern detrital drift.		
		11	Alluvium and river drift.		
		10	Post-tertiary valley or lake deposits.		
	EOCENE	9	Murree beds, sandstones and clays transitional with		
		8	Upper nummulitic beds, limestones, sandstones, clays.		
		7	Hill nummulitic limestone older than above.		
	CRETACEOUS	6	Limestones chiefly.		
		5	Ditto, black shale (Spiti) and dark sandstones.		
		4	Limestones, dolomites, breccias, shales, &c.		
	MESO- ZOIC.	TRIASSIC	3	Infra-triassic sandstones, breccias, &c.	} ^p same.
			2	Tanol series—Quartzites, sandstones, dolomites, &c.	
			(Observe: 2 and 3 may possibly or probably be parts of one group.)		
1			Attock slate series: Fine slates and grits, with limestone bands, some- times largely developed.		
PROBABLY PALÆOZOIC.		B	Intrusive traps, in Attock slates and Tanols also in metamorphic rocks.		
		A	Hazāra gneiss and the most crystalline altered beds.		

A. Highly crystalline metamorphic and azoic rocks.—It will be observed that I have given these rocks a separate place at foot of the list, an arrangement which might be supposed to convey the idea that they were really the oldest part of the series; and under ordinary circumstances it would appear easy to consider the granitoid gneiss as the fundamental portion of the whole. The observations made in the field have, however, shown indications of the presence of the singular Himalayan phenomenon of highly metamorphic rocks resting upon others possessing far less, or even in cases little or no, traces of having undergone metamorphism. Hence it is necessary to avoid hasty conclusions; for, if the stratigraphical superposition to be described really represents the normal sequence, the inference follows that among these metamorphic rocks a portion at least may be representative of palæozoic or even newer groups.

The unaltered rocks lie in the southern part of the district, the most altered in the northern region; but in passing from the former to the latter, neither a continuous, nor a simply interrupted or inverted, descending section is found. From the tertiary beds down to the slates, No. 1 (omitting No. 2 as doubtfully present), a descending series may be observed, with two breaks, the lowest of which is prominently marked. From these slates towards the Hazára gneiss, an ascending series, differing from that just mentioned, prevails; and in the gneiss region itself there are traces of interstratification apparent, the position and inclination of the bands being suggestive of these altered rocks occupying a high place in the northern series. The sequence could be accounted for if this northern series could be proved, by any unconformable contact, older and entirely different from the southern one; but at the point where operations had to be discontinued, it appeared to be gradually becoming evident that the great Tanol group of the northern series was passing laterally into the infra-triassic group of the southern and Sirban mountain sections (see Mem. Geol. Surv., vol. IX, part 3: Description of the Geology of Sirban). This would assert its position to be newer or higher than the Attock slates; while its upper

beds pass by prevalence of metamorphism into the transformed, crystalline, northern rocks with a strong appearance of underlying a most intensely altered portion of these.

The observation may in a general way be made, that the metamorphism of the rocks of the northern part of the district exhibits a lateral or geographical rather than any development coinciding with antiquity of the strata. Inversion, apparent or obscure, is often made to explain the difficulty of such a case, but the employment of this supposition may have a limit; as in the present instance, where, if the Tanol and infra-trias groups should prove identical, or even in parallel superposition, physical impossibility would be involved.



A glance at the accompanying diagram will explain this: the lower portion of the Tanol group (A) is very similar to the general aspect of the infra-triassic group (B), and as I have observed, they seem to unite in the Tandiani mountains, eastward of Abbottabad. But the infra-triassic group (B) rests unconformably upon the Attock slates, and its basal bed is a conglomerate largely made up of fragments of this slate series. Consequently the presumption is that the Tanol group is newer than the Attock slates, and not part of an inverted series, the oldest portion of which would be represented by the metamorphic rocks.

It is unfortunate that, however closely the groups A and B in the above diagram may be united, the succession upon the northern side of the crystalline area (C) is unlikely to become known, owing to inaccessibility of the country; otherwise, its comparison with the southern extra-metamorphic series would be in all probability instructive.

In the Pír Panjál region, not very remote from Hazára, an opportunity has occurred of studying the relations of both sides of a chain, the core of which is also formed of gneiss similar to, if not identical with, that of Hazára; and Mr. Lydekker, to whose research we are indebted for the information, is of opinion that a clear case of inversion is there established, and the series on each side of the crystalline axis is the same (*Rec. Geol. Surv. Ind.*, vol. XI, p. 30). Comparing that region with this, we should find little possibility of identifying the flanking series, although this Pír Panjál chain, between Kashmir and the Punjab, presents an assemblage of rocks continuous with those of the Kájúnág range, north of the Vedusta, or upper Jhelum, and doubtless continuous in a general way with the series of upper Hazára, perhaps, however, beyond the limits occupied by the Tanol and immediately associated type of rocks.

The Pír Panjál chain, with its gneiss and slates, &c., is considered as belonging to the Central Himalayan System (*Ann. Rept. Rec. Geol. Surv.*

Ind., 1878); its gneiss is recognised as re-appearing in the Kájúnág range (Lydekker, *l. c.*), and I can answer for the lithological identity between that of Hazára and the transported masses of the Kájúnág gneiss scattered along the Vedusta valley on the Murree route into Kashmir. Still I am quite unable to identify the other members of the Hazára series, generally or in detail, with those rocks which Mr. Lydekker has found displayed along the Pír Panjál range. To show the contrast, I propose, after describing the local series here, to place it and that of the country to the east (as recorded) in parallel columns.

The Hazára gneiss—is a completely crystalline granitoid rock, of whitish gray colour, composed of quartz, felspar, and black mica (biotite), white mica (muscovite) being often present as an accessory; and the rock is rendered porphyritic by an abundance of large twin crystals of pinkish or flesh-coloured orthoclase measuring from two to eight inches in height, more commonly from three to four inches being the longest dimensions. These lie in all directions in the matrix, sometimes affecting a linear arrangement, which may mark the former lines of now obliterated stratification. Schorl is locally present, and garnets are occasionally seen, both as rather unfrequent accessories. Separate bands or veins of rock crystal or opaque quartz are rare, but dykes of easily decomposing trap, apparently greenstone, are not unusual.

I have often sought near the junction of the crystalline rock with the adjacent schists for evidence as to its being intrusive or otherwise; and in some directions I have found what appeared to be distinct dykes or veins among the schistose rocks; but contrasting with these, and sometimes in contiguous localities, the schists exhibited a gradual transition towards the main granitoid mass by reason of great intensity of metamorphism, the region of actual contact being, however, defined within rather narrow limits.

For instance, on the southern ascent of the Susul Gali pass into Agror, I found masses of the adjoining schists included in the crystalline gneiss, presenting many gradations of alteration; and although the stratification was still discernable, parts were as crystalline as the adjacent gneiss, enclosing the same large felspar crystals, and other parts had assumed the form of a gneiss of much finer grain than that of the main mass.

In other cases, as near Mánasahra, detached masses of the schistose rocks were found entangled and enveloped amidst the gneiss without exhibiting this extreme amount of alteration, not being indeed more altered than the rest of the adjacent schistose beds. The country generally is one in which a wide or distant view often shows more of the broad structural relations than is gathered from close inspection of details; whilst in places, nothing is open to immediate view except small features, the continuity of which cannot be observed or relied upon, yet the facts concerning which must take their own place in forming conclusions. Thus, with regard to the gneiss, few traces of stratification are to be found in minute detail, though the outline of one of its principal masses, the Bahingra mountain, presents the normal Himalayan feature (common among the stratified groups) of a steep outcrop slope towards the plains, and a long gentle declivity towards the mountains of the interior. Coinciding with this form, and lying as if in alternately bedded masses, are groups of well stratified quartzites and schists,

sometimes cropping out along the whole of one side of a spur the opposite slope of which presents a sheet of the gneiss for many miles.

The whole aspect of the gneissic or granitoid region, so far as visited, gives the impression that an extensive series of mechanically formed detrital rocks has undergone transformation, the metamorphism being locally intense, and its extreme results expressed by a very abrupt transition from highly altered schists into gneiss itself.

Less highly altered azoic rocks.—The schists and quartzites adjacent to the gneissic area are, as a general rule, distinctly stratified; and, no matter in what direction inclined, they almost invariably dip towards exposures of the gneiss. They present the somewhat peculiar feature that they occupy, so far as yet traced, the deepest valleys, such as those of the Nainsúk, Sirun, and Indus; this feature, together with their dip, intensifying the appearance which they present of underlying the gneiss.

The metamorphism of these rocks bears a more or less constant relation of place to the margin of the gneissic tract, though it possesses no definite outer boundary. It appears on the left (Hazára) bank of the Indus to travel across the stratification of beds that are less altered further away upon the same strike, as though it were an effect related to the presence of the gneiss among the Buncyr hills in the wild tract beyond that river; or it might be perhaps inferred that the altered rocks here, lying lower than some in the neighbouring country, indicates the presence of plutonic ones at a depth beneath this region no greater than the distance within which the rocks at the surface nearest to the gneiss have been most metamorphosed.

The altered rocks in this situation consist chiefly of various talcose or micaeous schists, sometimes slaty, sometimes even conglomeratic from the presence of white quartz or quartzite pebbles; they are rarely calcareous, but sometimes contain bands of compact and rusty-looking dolomite or magnesian limestone.

B. Intrusive traps.—In both the more and the less crystalline metamorphic groups (as well as in the Tanol series), igneous rocks are not uncommonly met with as dykes or intrusions. One of these near the border of the Amb country, south of the Bahingra mountains, is of considerable size. Generally speaking, these rocks are of a dark, dense, variously crystalline greenstone, seldom porphyritic and never amygdaloidal. They do not present recognisable signs of having partaken of the metamorphism of the associated beds, but they are frequently weathered to an extreme degree, this condition perhaps having some connexion with their position.

1.—*Attock slates: (Azoic).*—The general appearance of this group has been already more than once described. It consists of various dark, olive, black or brownish fine earthy slates, sometimes with purple bands and occasionally interstratified with greenish fine-grained sandstones. Bands of compact, waved, pale and dark gray or rusty-brownish limestone are locally numerous; though comparatively rare in some localities, in others, as in the Gandgarh range, they assume an enormous development.

Here too these limestones include among their upper layers a band or bands of compact white or greenish semi-translucent waxy-looking thin-bedded marble,

associated with certain coal black graphitic shales, one or two very constant zones of which are known to the natives as the "*Súrma lurri*" rug or belt. Dolomitic and brecciated, or pseudo-brecciated, varieties of the limestones are frequently met with (see Section 1).

Geographically the slates intervene between the mesozoic limestones of the southern Hazára hills and the Tanol group of the northern series. An isolated patch of them and their associated limestones stretches from the Nainsúk valley, forming the lofty peak of Mián-Jáni-ka-Chauki, and passing westwards by Sujkot among the limestone hills south of the Dore valley. Their stratification is much disturbed; cleavage is prevalent in places along so many planes that the rock is cut up into splinters; in others it is scarcely developed, and the thinly laminated structure of the slates enables them to be split into flags or even bedding slates, of inferior quality.

A long fault forms their southern boundary for a considerable distance, another brings them in contact with the northern side of the Sirban mesozoic exposure, and still another forms their northern limit for many miles, coinciding with a long valley running from Haripur towards the north-east, so that this fault passes northwards of Abbottabad.

The unconformable infraposition of these slates to the infra-triassic rocks of Sirban has been pointed out in the paper on that mountain (*l. c.*); their junction with the Tanol group is mainly a line of dislocation; but where this is not evident, they appear to underlie those rocks; and they are seen unconformable to, and apparently beneath, beds similar both to some of those in the Tanol group and to the Sirban infra-triassic beds, on the road from Abbottabad to Mangli (or Mangal); they also unconformably underlie the *Dicerocardium* limestone of the Zyárat hill close to Hassan Abdál.

The main strike of the slates, and their most extensively recognisable fault lines, follow the north-east south-west bearings of the rocks and ranges west of the river Jhelum with varying regularity. They possess an almost monotonous unity of aspect which imparts itself to the ground they form, this everywhere presenting the same minutely mammilated and steeply fretted surfaces, coated with a scaly layer of finely divided detrital fragments, giving the ground a peculiar soft greenish-olive tint. It is only when limestone bands are present that the outlines become rugged.

As a rule, in the southern part of Hazára, the slates are unaltered along the side of their exposure next to the mesozoic and eocene limestone hills; but on the opposite side, between Gandgarh ridge and the Indus, as well as generally towards the Tanol group, some amount of metamorphism has rendered them silky or lustrous, and traces of alteration are much more evident in their associated limestones which often present a curiously matted foliation.

Conglomerates, properly speaking, have not been found in the Attock slate group; but a few of the more coarse-grained beds were observed to enclose lumps of quartz or quartzite scattered through the rock, and not unfrequently presenting pebble-like forms.

These Attock slates of Hazára have been found, as usual in their more westerly extension, to contain no vestige of organic life. Even the limestones

associated with them, and evidently belonging to the series, though in some places having a pseudo-fossiliferous appearance, seem wholly destitute of any organic remains discoverable by the naked eye or the pocket lens.

But in the southern portion of these rocks, along the margin of the mesozoic limestones, there are limestone bands included among the slates in which I have in two or three instances found fossils. At one spot near the road from Khánpur to Haripur (between Padni and the road) I found highly disturbed or vertical limestones containing the well marked sections of *Dicerocardia*, &c., and again in a limestone ridge little more than half a mile due west of Bandi Atáhi (called by the people of the locality Bandi Tai Khán), and east-south-east of Huveliyán on the Dore, I found imperfect and fragmentary casts of crushed *Ammonites*.

Although there are in the vicinity of these fossil-bearing limestones others of the hard, frilled, and peculiar aspect of those found in the slate series, I am by no means prepared to say that these beds with the fossils belong to that series; I regard them as more probably belonging to the adjacent mesozoic series, let into their present position by dislocation, and subsequently so wedged among the slates as to make it appear that the present is their original situation. My reasons for this conclusion are shortly, that the *Dicerocardium* limestones of Hasan Abdál and Sirban are evidently unconformably superior to the slates, and that the rib of limestone with *Ammonites* is almost continuously traceable into the mass of mesozoic and eocene limestone hills crossed by the upper road from Murree to Abbottabad.

For some time past these Attock slates have been provisionally considered of silurian age, from the recorded discovery by Dr. Falconer of "lower silurian fossils" in the Kábul river of the Pesháwar valley (in slaty rocks?) derived from the Khyber hills on the same general strike. Their silurian age was accepted by Dr. Verchere, and adopted by Dr. Waagen and the Geological Survey; but it has never appeared that the correlation was quite correct, nor have I been able to trace any thing stronger than indirect allusions to Dr. Falconer's discovery; such as Major Godwin-Austen's reference in his paper on Kashmir (Quar. Jour. Geol. Soc., Lond., Vol. XXII, p. 29), where he says, "As lower silurian fossils from the Khyber hills were found by Dr. Falconer in the gravel of the Kabul river, as also by Colonel Strachey on the Niti Pass, the great masses of slaty and metamorphic rocks which in this part of the Himalayan chain underlie the carboniferous beds may be referred to a lower palæozoic series." Major Vicary mentions a few of the genera found by Dr. Falconer above referred to (Proc. Geol. Soc., Lond., Vol. VII, p. 45), but it does not appear that the whole or most of these are strictly silurian forms. Still the impression conveyed is too definite to have been founded on a mere guess. Nor does it after all appear that the identity of the Attock slate group and the Khyber beds is at all fixed, though very similar slaty beds are said to occur beyond the Khyber pass towards Jelálábád. Hence the age of these slates can hardly be considered established with sufficient accuracy to warrant their being regarded definitely as silurian, while the probability is that they are palæozoic. (See Manual, p. 500.)

2. *Tanol group: (Azoic).*—Lying between the Attock slate region and the metamorphic area is a great group of rocks, the existence of which was unknown until the past season, and the analogues of which I am unable to discover among the recorded sections of Kashmir and the Pír Panjál. I have called these rocks for sake of distinction the “Tanôl” group, from the ancient name of the country they occupy.

These beds are always associated with the schists of the northern series, and they appear to pass both into and underneath a considerable section of these schistose rocks. They comprise an enormous thickness of gray or drab quartzose or quartzite rocks, in rapid alternation with dark earthy bands, flaggy, shaly or slightly schistose. Many of the dark intervening bands remote from the gneiss are in appearance scarcely altered, and have much the look of Indian jurassic plant beds. Others of the alternating layers are exceedingly fine, unctuous, slaty argillite, sometimes associated with conglomeratic slates, the pebbles of which, ranging up to the size of goose eggs, are usually formed of white quartz or quartzite.

The quartzites or quartz rocks frequently show lines of oblique lamination, or other lines of deposition; and they include amongst them beds of almost unchanged sandstone, the weathered surfaces of which have the small warty protuberances such as are frequently observed upon certain mesozoic sandstones in the peninsular Indian area.

Some of these Tanol rocks, towards the apparently upper part of the group, are of a clear grayish white color, soft enough to mark the fingers when handled, and with these the slaty rocks of paler color prevail. The soft white rock is not calcareous, nor has it a strongly argillaceous appearance; reduced to fine powder it is but slightly soluble in acids, even when boiled for a considerable time: it fuses on thin edges to a white glass, and in powder on charcoal to a somewhat coherent semi-fused mass, giving no alumina reaction with nitrate of cobalt, nor any distinct magnesia color. This powder fuses with effervescence in carbonate of soda, but is not quite fusible in borax. The color of the bead given with reagents was not definite enough to form an opinion by. The specific gravity of the pieces examined was about 2.78. These soft white beds, though retaining a good deal of their detrital aspect, have undergone so much metamorphism that it is uncertain what kind of sandstones they originally were; and yet the strata amongst which they are intercalated do not seem to have suffered extreme alteration.

Occupying synclinal folds, or else occurring at various horizons, in the Tanol group are thick zones of variously colored pseudo-brecciated, silicious, cherty or compact gray, black, and buff dolomitic limestone, with which are occasionally associated intensely black graphitic and sulphurous shales, or else purple and red sandstones and slaty bands.

The Tanol group extends from near Mangli (and probably further east among the Tandíání mountains) by Sherwán towards the Indus, passing north of the Gandgarh range. Its relations to the Attock slates on which it seems to rest are obscure, the junction being frequently either a line of dislocation or concealed by quartzose debris; but still the disposition of the two groups in the neighbourhood of the lower Sirun and Dore rivers is one consistent with unconformity.

Trap rocks, chiefly intrusive and perhaps intrusively interbedded, are found in the group, mostly among the more metamorphosed portions, and of similar dense crystalline basic kinds to those of the altered rocks.

I have not been able to detect any organic remains among these Tanol rocks.

The apparent superposition and probable unconformity of the Tanol upon the Attock slate group, and the presence of silicious dolomites and red sandstones in the lower part of the former, as well as in the lower part of the infra-Trias of Sirban mountain, are points of resemblance which would indicate a connexion between these infra-triassic beds and the Tanols; but the latter exhibit a thickness enormously greater than that of the group overlying the slates in Sirban, nor has the distinct evidence of conglomerate formed of slate debris been found at the base of the Tanol group, neither have any fossiliferous limestones or other beds identifiable with the Sirban Trias been met with. Notwithstanding this, on tracing the Tanol group and the Sirban beds to the north-east, they seem to unite in one great series in the lofty mountains near Tandianí, sweeping over an anticlinal axis near the camping-stage of Mangli or Manghal. The decision of this important point must be reserved until the Tandianí hills can be examined.

The thickness of the Tanol group exposed in the sections from the Mián-khaki stream northwards can scarcely be less than 20,000 feet, up to the place where they pass into the metamorphic rocks. Possibly some part of this thickness may be repeated; in so disturbed a region it is difficult to say repetition does not occur, but general appearances are against it. Nor is it easy to account for the absence of the mesozoic series of the southern hills unless they may possibly be partly represented by some of the dolomitic zones, or else metamorphosed beyond recognition. (See Section No. 4).

Far away to the north, in the Palleja heights, overhanging Bogurmang, I could see among the snows a basin-like arrangement of strongly bedded rocks as though resting unconformably upon the metamorphics. Of these the only specimen I could obtain was one of a dark dense limestone. Should limestones prevail, and the sharply scarped form of the cliffs looked as if this were likely, the mesozoic series may in part be represented there, or perhaps some of the Kashmir carboniferous or other groups.

The Southern Hazdra Series.—Of the rocks in this part of the district more was already known than of those to the north. The limestones of the hilly tract between the Attock slates and the Ráwalpindi upland or the Murree hills, present an extremely confused, contorted and faulted assemblage of mesozoic and eocene strata, an epitome of which is afforded by the instructive sections of Sirban mountain described in the memoir already quoted. The main features of the whole tract are, a large development of the triassic and of the great hill-nummulitic limestones, the disappearance westward of the jurassic (Spiti) shales, and their place being taken by limestones containing *Trigonia*, amongst which *T. ventricosa* is a prominent form, together with some poor and fragmentary *Ammonites*, *Belemnites*, *Gryphæa*, and small brachiopods; also the disappearance of the infra-Trias group of Sirban, which is at least no longer recognisable to

the westward, nor has the cretaceous band there observed been found reappearing with the same character, if at all elsewhere in this district.

For fuller detail I refer the reader to the already described Sirban sections (Mem. Geol. Surv. Ind., vol. IX, Art 3, p. 331); but to convey a general idea here, I abstract the table of succession given in that paper at p. 2, viz.—

6. NUMMULITIC.—Thick limestones with some shales, fossils in places.
5. CRETACEOUS.—Thin-bedded limestones without fossils apparently.
Impure ferruginous sandy limestone, weathering rusty—fossils.
4. JURASSIC.—Black Spiti shales.

Unconformity.

3. TRIASSIC.—Thin-bedded limestone and slaty shales, dolomite, limestone; fossiliferous (*Megalodon* and other) beds.
2. BELOW THE TRIAS.—[Infra-Trias] Hæmatite, dolomite, quartzite, sandstones and breccia.

Marked Unconformity.

1. PALÆOZOIC?—Attock slate.

Of these groups the Attock slates, ascertained from larger developments to be the same group exposed at Attock, have been already described.

The infra-Trias, however, requires a few words of description in order to enable a comparison to be formed between it and the Tanol group. It seemed to show a triple sub-division, the lower one consisting chiefly of red sandstones, red shales, and red quartzitic dolomites, underlying another zone of dolomites of lighter color often highly silicious and of very considerable thickness. These words would apply almost equally to those well marked red and lighter colored dolomitic zones of the lower, but not lowest, part of the Tanol group. The sections given in the Sirban memoir may be compared with that crossing the Tanol group, No. 4, appended to this paper.

The third sub-division, composed of hæmatitic rocks, quartz breccias, sandstones and shales, seems less capable of recognition to the north; but it might be there subordinate either from lateral change or blending with the dolomitic zones.

4. *Triassic*.—In this group the further examination of Hazára has revealed the existence of a great development of limestones with some shales. Many of the former show features characteristic of the Sirban exposure, yet are most frequently without the arrangement into more or less defined, though sometimes obscurely, fossiliferous zones. Owing to this local character the exact lines of the Sirban section have not been traceable amid the larger and thicker exposures elsewhere. Although the most characteristic feature,—the presence of numbers of impacted *Dicerocardia*, sometimes accompanied by shells of the *Megalodon*, visible in section only,—has been observed in one or two localities; the point of itself is insufficient to establish actual identity of these fossiliferous beds, but decisive as to the general age. Outlines of these fossils from the Sirban rocks are figured at page 8 (338) of the Sirban paper, l. c.

Other fossils among the triassic beds generally are so few, so fragmentary, and so rarely met with, that it is often doubtful whether the beds are really

triassic or jurassic, nothing being left for guidance but the not very definite point of lithological character.

The thickness of these rocks in the neighbourhood of Khánpur, however difficult to fix on account of plications, can scarcely be estimated at less than 3,000 or 4,000 feet, perhaps more than double the amount of the triassic series of Sirban, where the best exposed sections show the formation sheeting the northern side of the mountain, with inclinations of less than 35° , over a slope a mile and a half long with a rise of 2,000 feet. This being taken as the basis of calculation affords the inference that the Sirban trias formation may have a total thickness of between 1,500 and 2,000 feet.

The distribution of the formation as far as traced is shown upon the sketch map annexed; it seems to have suffered extensive inversion near Bagnotar on the Murree and Abbottabad road.

5. *Jurassic*.—The jurassic rocks of the southern region of Hazára are very subordinate, as to extent or thickness, to the underlying group. They are, however, traceable by numerous complicated exposures among the disturbances so prevalent in these hills. They appear amongst masses of nummulitic beds, at Shah Kabul summit, in the Khánpur country, as a rusty group of earthy limestone, shales of dark and light color, and occasional sandstone bands, identified by Dr. Stoliczka as similar to his Gieumal sandstone of other Himalayan regions. Similar rocks reappear near Garm Thun; and they are met again, though scarcely ever with exactly the same character, edging the southern frontage of the Márgalla range, and in the interior of the mass of hills crossed by the old bridle track from Murree, *vid Mári*, to Abbottabad.

In the higher hills the jurassic formation includes in places a well-developed zone or zones of black Spiti shale, containing fossils characteristic of that group in Spiti, but both these shales and their fossils appear to be entirely wanting to the west, where a band almost made up of ill-preserved *Trigonia ventricosa* (not found in the higher hills) appears towards Shaladitta, associated with layers containing *Ammonites*, *Gryphæa*, and *Belemnites*. But it is not clear whether these fossiliferous beds to the west are newer or older than the Spiti shales,¹ the groups never having been found in contact or in the same section; and the relation in both cases to the succeeding cocene rocks, so far as can be made out, being that of conformity.

The whole formation seldom exceeds a few hundred feet at most; but where its lowest limits may be, among limestone masses, part of which are at least triassic, though the upper portion may be newer, it is impossible to say without better palæontological evidence than is available, and without the reappearance of the Sirban discordance.

6. *Cretaceous*.—The few beds referred by Dr. Waagen from their fossils to this formation at Sirban are the only established case of its occurrence among these hills. In many places, however, there intervenes between the known

¹ These western fossiliferous jurassic rocks are stated in the lately published *Manual of the Geology of India*, p. 503, to "appear to be a continuation of the Gieumal sandstone." So far as I am aware, there are no sufficient grounds for the assertion as yet discovered.

jurassic and the nummulite-bearing limestones, a mass of light or dark-colored limestones without fossils, which perhaps belongs to the cretaceous period.

The fragmentary *Ammonites* found in a limestone rib southward of Huvelian (see *ante* p. 121) on the opposite side of the Dore valley from the cretaceous band of Sirban, occurred in limestones with somewhat the aspect of those of the cretaceous zone; but it is not even known whether the specimens can be determined.

7. *Nummulitic*.—The nummulitic eocene limestones of these hills presents no peculiarity beyond the general features described in former papers (Rec. Geol. Surv. Ind., vol. VI, pt. 3, vol. VII, pt. 2, vol. X, pt. 3; Q. Jnl. Geol. Soc., London, vol. XXX, p. 61, vol. XXXIV, p. 347).

It occurs very extensively, yet its thickness, which must be very great, is difficult to determine on account of the frequent faults and the disturbance of the beds. One section from Murree northwards would indicate a greater thickness than 2,700 feet for what is but a part of the series; and from 3,000 to 5,000 feet may be a probable, though necessarily a very conjectural, estimate for the whole.

These dark gray eocene limestones of the outer Himalayan region, alternating frequently in some places with olive shales which are almost entirely absent in others, and containing sometimes an abundance of small Foraminifera, sometimes scarcely a fossil distinguishable with a lens, are in a manner peculiar to the northern regions of the Punjab, as has been already pointed out (*l. c.*, above). There seems to be a possibility that in the higher portion of the hills, traversed by the upper Abbottabad and Murree road, the group includes in its lower part dark red and blackish gypseous shales and sandstones of the aspect of those found in the base of the succeeding tertiary sandstone series, but the point is obscure. There is also a considerable appearance of transition from the upper or outermost beds of the Hazára hill-nummulitic rocks into the upper nummulitic zone near Murree, which is transitional with the lower tertiary sandstones and clays just mentioned. The apparent passage is deducible from the arrangement of the rocks in the region of the abnormal contact between the Hill limestones and outer tertiary zone, and therefore less trustworthy than it might be; still such appearances, even in disturbed localities, should not be overlooked (see Section No. 5 annexed).

The upper nummulitic beds of this district, scarcely appear within the hilly tract from Mochpura mountains westward in other than doubtful exposures. Some of its beds are faulted into junction with the hill-nummulitic and jurassic rocks between Shaladitta and Garm Thun, on the road from Ráwalpindi to Khánpur; and the faulted mass of red rocks with gypsum, in the Haro Kas below Dungagali (north of Murree), may either belong to this group or be intercalated, as just now mentioned, at a much lower position with the eocene limestones.

Another more extensive exposure of red argillaceous and arenaceous rocks was met with this season capping the Lachikhun mountain, in the range overlooking the Nainsúk at Ghari Habibula from the east. Lithologically these might represent a variety of the lower tertiary sandstones (Murree beds), but

have a harder, more slaty and more prominently red aspect. They are intersected by numerous parallel veins of white carbonate of lime, which is one of the characteristic appearances of the Murree beds near their disturbed junction with the hill rocks. There are, however, no such masses of nummulitic and mesozoic limestones associated with these beds as occur further to the south-west. Dolomites, limestones, and black carbonaceous or graphitic shales appear immediately beneath them; but these beds have much more the aspect of the infratrias or Tanol rocks than of the newer limestones, &c., and none of them contain fossils so far as could be discovered. On one spur of the mountain near Kulis village, a situation which would indicate an inferior position to the red beds, I observed numerous shaken angular blocks of limestone containing *Nummulites*. These, although they could not be pronounced *in situ*, did not appear to have been far removed from their original place, and they would indicate an extension in this direction of the Hazára eocene formation.

The whole of the red series and associated beds on this range appear to rest unconformably upon the metamorphic schists, of which the lower half of the mountain mass is entirely composed; but no clean sections could be observed, and snow concealed much of the higher ground.

A small vein of galena among the schists in the Kakal ravine, not far from Kulis, is only worth mentioning to state that the quantity is so very small as to be economically worthless, so far as this one vein is concerned, and unless others of much larger proportions are concealed in the vicinity. On examination at Calcutta specimens of the ore were found to be argentiferous, as is very commonly the case.

Before noticing the more superficial and less important deposits, it may be useful to glance at the comparative aspect of the two great series of rocks—those of the Himalayan system in Kashmír and those of the Hazára region, still further west. In order to present the state of the case as definitely as possible, I have taken the Kashmír series from Mr. Lydekker's papers, and placed it side by side with that of Hazára in a tabular form (annexed).

Commencing with the older rocks, it will be observed from what I have already stated, that the first discrepancy to be met with is in the position of the gneiss of the two regions. Mr. Lydekker refers to two kinds of Himalayan gneiss, but considers that occupying all or most of the gneiss areas on his map as of one kind, except perhaps the central portion of the Zânskâr range, (not marked on his map, (Records, Vol. XI, p. 30) but forming the north-west south-east watershed north-east of and above Darwas). This great expanse of identical gneiss, presenting the same relation of conformity and transition into the overlying silurian schists, is of course newer than the "central gneiss" of pre-silurian age. The Kájúnág ridge belongs to the Pír Panjál range, and its gneiss is at least lithologically identical with that of Hazára. But, though in the Pír Panjál this gneiss forms so well marked a base to the stratigraphic system of a widely-extended area, and the apparent alternation of the gneiss with quartzites and schists in Hazára affords a further point of similarity, its general situation with regard to the rest of the Hazára series conveys no appearance of its being a fundamental rock or the basal member of the stratified series.

Comparative Table of the Kashmir and Hazara Series on different sides of the Jhelum Valley synclinal or deflection of the Himalayan strike.

(So far as at present known).

HAZARA SERIES.		KASHMIR SERIES.	
CAINOZOIC ...	Pleistocene ... { Northern detrital drift Alluvium and river deposits Post tertiary valley or lake deposits.	Siwalik ... { Alluvium. Kar-wahs { Upper. Lower—Nahan.	... { Probably equivalent to the post tertiary of Hazara.
	? { Murree beds. Upper Nummulitic beds	... { Kargil. Dagshai Sabarhu	... { These groups may be equivalent to the Murree beds. These beds are identical in both regions. 3,000 to 5,000 feet of limestones absent in Kashmir.
	Eocene ... { Hill Nummulitic limestones	... { Sirmur	... { Unknown in Kashmir as yet. Unrecorded as yet in Kashmir.
MESOZOIC ...	Cretaceous ... { Cretaceous limestones	... { ...	... { The upper beds may be those of Sir Ban in Hazara.
	Jurassic ... { Jurassic limestones, &c.	... { ...	... { From description in both regions not unlike.
	Triassic ... { Triassic limestones, &c. { Upper Infra-triassic sand-stones, breccias, &c., and Tanol series, Quartzites, &c., metamorphosed northwards, and passing into gneiss and crystalline rocks.	Trias ... { Upper Lower	... { The Kiol series only seems to present any similarity to the Tanol group.
PALEOZOIC ...	UNCONFORMITY.	Carboniferous { Including Kiol Kiol and great lime-stone.	... { The Attock slates contain limestones the silurian of Kashmir does not, but the Pangi slates to S. E. do.
	? { Attock slates, partly altered	Silurian ... { Pangi slates Panjal rocks	... { The gneiss is difficult to recognise as the same in both regions, though partly lithologically identical.
	The Hazara gneiss is identical with some of that in Kashmir, but differently placed.	Gneiss ... { Gneiss	... { The two unconformities in the Hazara series are unrecorded in Kashmir or Jamu.

Mr. Lydekker has specially pointed out the conformity of this Himalayan gneiss to the overlying silurian strata, but in Hazára, whether the contact rocks may be correlated with his Pír Panjál and Pángi groups or not, the manner of their junction as described above (see section No. 4), the enclosure of detached altered, and more highly converted metamorphic schists, within the gneiss, also the occurrence of dyke-like veins of gneiss amongst the schists, would show, that however conformable the original rocks may have been, this relation is rendered more than obscure by the intensity of the metamorphism they have undergone.

Thus, though the gneiss of the two regions may be identical in hand specimens, its diversity of arrangement in the two districts would point either to the occurrence of two different gneiss formations, or else, what is perhaps more probable, to the occurrence of two distinct modes or degrees of metamorphism affecting the rocks within its range differently in each case, coinciding with the stratification in one case, crossing it in the other.

The next point of dissimilarity in the features of these two regions is in connexion with the rocks resting immediately upon the gneiss. In Hazára there are no particular zones having this relation as yet explored; still the schists, &c., of Lachikhun mountain would seem to be a continuous portion of those of northern Kashmir, and may yet be found more palpably resting upon extensions of the Hazára gneiss than has hitherto appeared.

The more than 2,000 feet of blue and black slates, and flaggy slates with blue and fawn-colored sandstones, splintery grayish shales and locally abundant limestones of the Pángi series, scarcely find a counterpart in the Attock slates, though the general description more nearly resembles these than any other portion of the Hazára groups. But the Attock slates have never been observed passing downwards conformably and with intercalation into metamorphic rocks with alternations of gneiss: nor have they been known to contain erratic (*i.e.* travelled) fragments of angular and waterworn gneiss. Hence the Attock slates do not seem to represent the silurian of the Kashmir sections; or if, notwithstanding, they are a modified extension of that silurian formation, they differ in not being conformably associated with the gneiss.

The Panjál series—of black and green slates, sandstones, amygdaloidal rocks, brown sandstone conglomerates containing pebbles of quartzite and slate, white quartzites and sandstones, and below all black slates with pebbles of gneiss and quartzite, granitoid gneiss with bands of slate and quartzite,—seems also to have no closely similar group among the Hazára rocks. The gneiss with bands of slate and quartzite has indeed a certain resemblance to the association of the gneiss and schists of this country, and conglomeratic beds are not unknown among the metamorphic schists; but the whole aspect of the group, despite the entire absence here of the amygdaloidal beds, would seem to possess a rough similarity to the Tanol group, were it not that the latter contains limestones and dolomites, unrecorded in the Panjál series, and it has not the relation of conformable and transitional superposition upon the gneiss. Another difficulty is met with in seeking for the analogues of the Kashmir carboniferous beds in Hazára. The general diversity of the sections in these two adjoining areas prepares one for a difference here also, and I am unable to point to any Hazára group which would

occupy the place of these rocks to the eastward, or which resembles closely any carboniferous exposure in Kashmir, as described by others or seen there by myself.

Mr. Lydekker suggests that local differences in the carboniferous sections of that country may be accounted for by supposing separate areas of deposition. If the differences increase towards Hazára, it would be rash to say the formation is as wholly unrepresented as it appears to be; but I have never found a trace of any of the fossils of this group such as I have met with both in the Salt Range and in Kashmir regions. One unfossiliferous limestone formation may so closely resemble another, that I cannot say whether the massive limestone formation of Gandgarh may not present some identity with that of the Krol group, which I have never seen, but which has been classed with the carboniferous beds of Kashmir, nor yet whether it is similar to the great limestone of the Jamú inliers. The slates of Hazára certainly have a less shaly look than those of the carboniferous group in the Lidar valley-Kashmir.

The occurrence of quartzites, black shales (graphitic or carbonaceous) with nodules of iron ore, and limestones in both the Kiol and the Tanol groups might indicate some identity, but though dolomites are more characteristic of both the latter series and of the infra-triassic of Hazára, and are not uncommon in the Salt Range carboniferous, they do not seem to be strikingly developed in the Kiol group of Kashmir, but rather to be the prominent feature of its trias formation.

The triassic rocks of Hazára are doubtless the same as some of those in Kashmir; and to judge from the description of the latter, it does not appear unlikely that the beds separated in the Sirban series as infra-trias are also included with the Kashmir formation.

For the jurassic rocks of the present district, I find no equivalents recorded in Kashmir; and the same remark applies to the cretaceous formation; though the Spiti shales of the country east and north of the Kashmir region are characteristically displayed in Hazára, with several of their fossils.

The hill nummulitic limestones so extensively developed in Hazára are not known as yet to exist in Kashmir, where, in the fringing zone of limestones outwardly flanking the Pir Panjál, the carboniferous formation takes their place in the general structural sequence.¹ But the upper nummulitic zone of the exterior of the Hazára hills is identical with the Sabáthu zone as determined by Messrs. Medlicott and Lydekker in the Jamú country and near Muzaffarábád; I have myself found it on the east side of the Jhelum north of the junction of the Nainsúk with that river².

From this brief glance at the want of uniformity between the extensive geological series of the two regions, it appears to follow that considerable diversity of conditions must have accompanied their formation. In regarding this possibility it should be remembered that, though the infra-jurassic unconformity, locally seen in Hazára, can scarcely be declared absent in Kashmir till

¹ In a paper and map in Q. Jl. Geol. Soc. Lond. Vol. XXXIV, p. 347, etc., I have represented this fringing zone as mesozoic as originally shown in Rec. Geol. Sur. Ind., Vol. IX, p. 155.

² A different view of the correlation of the nummulitic rocks east and west of the Jhelum has been suggested (Rec. Geol. Surv., India, IX, p. 57), whereby the lower or hill-nummulitic limestone is not regarded as lower than the Subáthu group, but as only a different form of contemporaneous deposits (see also Manual, p. 566).

jurassic rocks are found, there is no record in the Kashmir sections of the very complete break at the base of the Infra-trias group in Hazára. The slight and broken chain of similarities between the series commences with the lithological identity of the gneiss, is most developed, apparently, in the trias formation, and ends with the upper nummulitic tertiary group, or the far more recent Karewah beds. Excepting perhaps the most metamorphosed rocks, all the others present more of disparity than unity, and the reason for this might no doubt be found if the early history of the western Himalayan rocks and ranges were more completely known.

Mr. Medlicott has pointed out (Records Vol. IX, pt. 2, p. 51) that the elevation of the middle Himalayan area to the eastward of this country dates from early or middle secondary times, and that disturbance was specially displayed towards the close of the eocene period; but that from this early secondary date to the most recent (Siwalik) tertiary times no disturbance took place in the region of the Jhelum, that is, in a part of the country to which the present remarks refer. The later observations of Mr. Lydekker on the carboniferous series of Kashmir, indicating separated areas of deposition, and the denudation of the Attock slates of Hazára, besides the evidence afforded by the fragments of ancient gneiss in the Pangl series and rolled quartzite pebbles in the Tanol conglomerates, all these would seem to point to various stages of disturbance and repose of earlier date than mesozoic times in the western Himalayan regions; the absence also of two of the mesozoic formations, so far as distinct records go, in Kashmír, together with that of the great eocene hill-limestone so largely developed in Hazára, may possibly be connected with distribution of depositing areas consequent upon elevation in later mesozoic times. Hence the localization of the central Himalayan disturbance, with regard to the deposition of the later tertiary groups, may bear limitation to the early eocene period; and the discordance between the Hazára and Kashmír series may be due to more or less local or intense disturbances of these mountain regions at various dates from an early palæozoic to the most recent tertiary or even post-tertiary period, if the dip of the Karewahs is attributable to elevation along the Pír Panjál range or subsidence on the opposite side of the Kashmír valley.

10. *Post-tertiary deposits.*—These are not so prominently seen in Upper Hazára, as in the lower country to the south-west, but the Pakli valley and the Hazára plain are filled with detrital accumulations which may be referred to the older kind of alluvial formation. There are also semi-fan-like accumulations in the neighbourhood of Abbottabad, and thence towards Mánasahra, the original continuous surfaces of which have long since been deeply cut into by the torrential streams of the country, indicating a considerable age for these fans.

The detrital accumulations of Lower Hazára, and the Dore river are largely formed of slate debris: and the gneissic or syenitic gravel, found further west towards the Indus, has not been seen beneath these deposits. In parts of the Pakli plain, however, I found a limestone drift sometimes cemented by carbonate of lime, which appears most probably to have come from the southern mesozoic or eocene hills, as it was met with on that side of the plain.

It seems to me very probable that these deposits are of the same age as the

Karewahs of Kashmír; but I would not on that account convey the idea that they were of Siwalik or even of tertiary age.

11. *Alluvium and river deposits*.—The alluvium of the Dore and other rivers of Hazára, in low situations, is of light drab silt, not calling for particular notice. Along the Indus the river deposits occur for considerable spaces in the form of terraces, rising to more than 100 feet above the river. The material brought down by this river is also more sandy than in other cases.

A good example of the fan-form of river deposit occurs a couple of miles north of Garhi, along the lower part of a mountain torrent from the Lachikun range. The outlines of similar fans were also seen far above the highest point visited on the Indus, but within the Amb territory, which is difficult of entry without much official correspondence with the political officers.

12. *Northern drift*.—I use this term instead of the more simple one "erratic drift," which would appear to convey to some Indian geologists a closer connexion with glacial geology than is necessary to the purpose. By northern drift then is here meant that influx of travelled masses, which has followed the course of the Indus from the north, and been distributed over large spaces of the Ráwalpindi plateau, to a distance (I am informed by Mr. Theobald) of 25 miles from the river. These blocks are easily recognizable all along the Upper Indus, as far as I went, to be the same as those further down its course. They often rest on the terraces, and some of them are of very large size. They are even more numerous along the narrow part of the river valley than in the lower country. This drift of foreign or transported blocks has penetrated from the northwards up the course of the Sirun and Dore discharge, as far as the point where their united valley begins to cut across the end of the Gandgarh range; and at one or two points huge boulders of granite or granitic gneiss seem once to have almost entirely blocked the valley. One of these boulders, between the Turbela-Haripur road and the river Sirun, composed of a fine grained granitoid rock, not the Hazára gneiss, measured $22\frac{1}{2}$ feet \times 36 feet \times 24 feet, and has a girth of 109 feet.

The boulders are scattered over a considerable space eastward of this stream, where the ground is lower than to the west, and there is a regular drift of well-rounded gneiss blocks, often larger than paving stones, which terminates in two high mound-shaped hillocks at the upper end of the gorge near Dáre village. This disposition of the transported materials shows that many of them may have found a passage through this opening, and floated away to the southward, if rafted by ice, at a time when the Indus ran at a higher level, and most of the lower country may have been occupied by a lake. Some large limestone blocks (from what group derived being uncertain), which occur near Sultánpur on the Haripur—Hasan Abdál road, may be connected with this line of transport.

One remarkable and very large mass of the triassic or supra-trias limestone of Sirban rests perched at about 4,300 feet on the slate hills of the opposite side of the valley above the village of Sulhud. It is from 25 to 35 feet high, and 127 paces in circumference. This mass seems to have slipped from the Sirban mountain at a time when the deep valley between it and that elevation had not been excavated, and its forcible passage northward appears to have somewhat disturbed the edges of the slates forming the surface beneath. I could find upon it no traces of

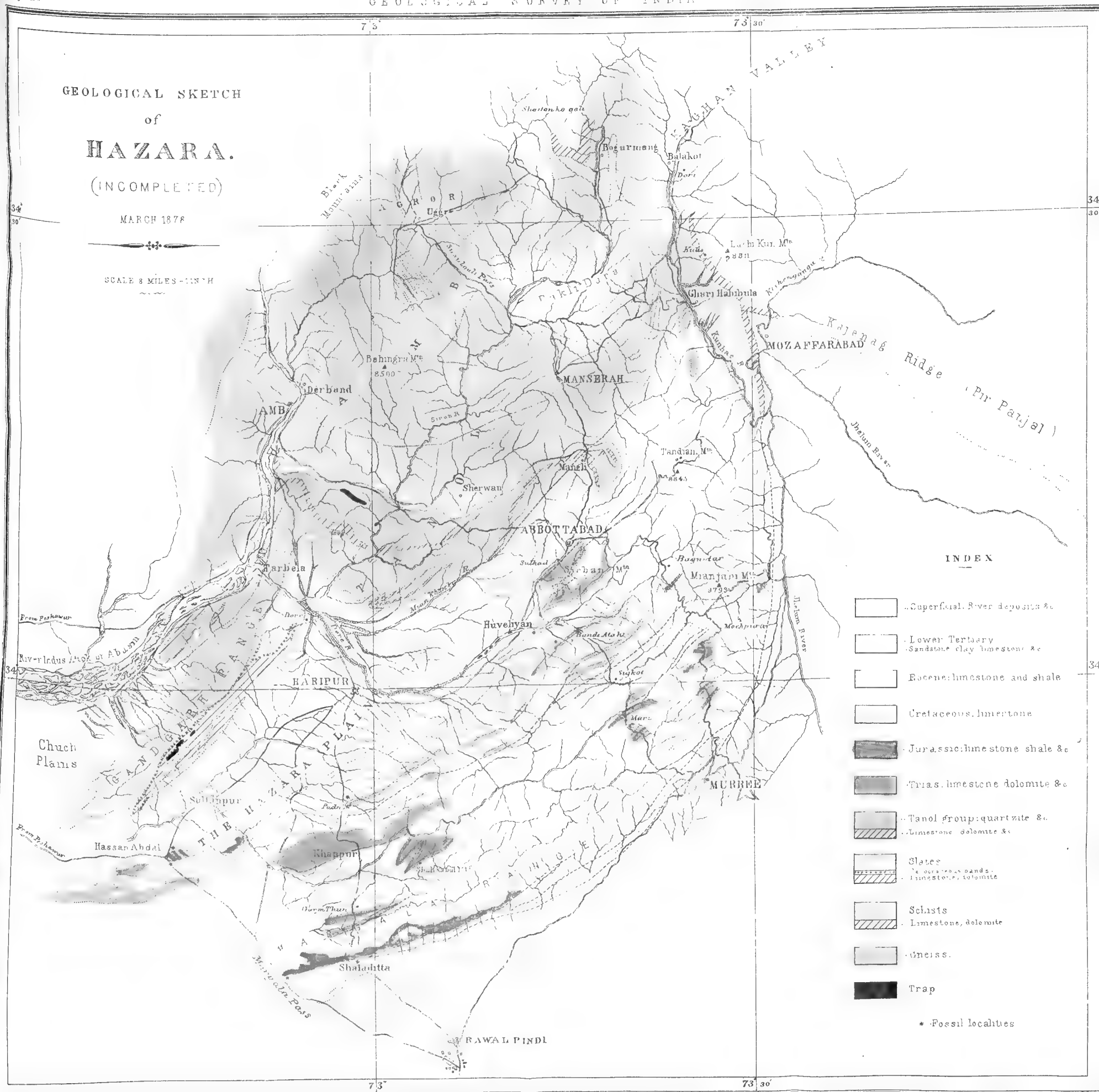
GEOLOGICAL SKETCH
of

HAZARA.

(INCOMPLETED)

MARCH 1878

SCALE 3 MILES = 1 INCH

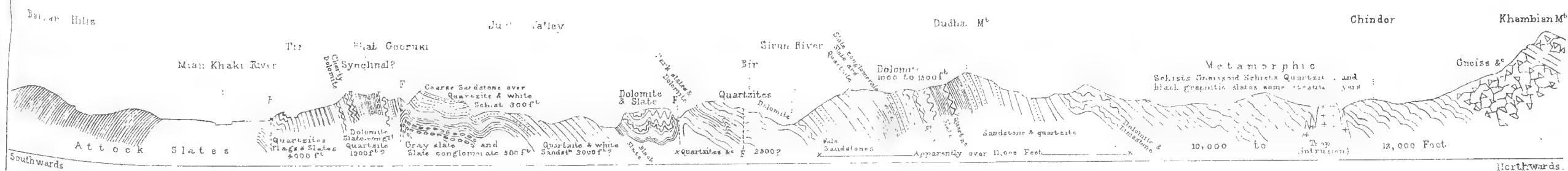


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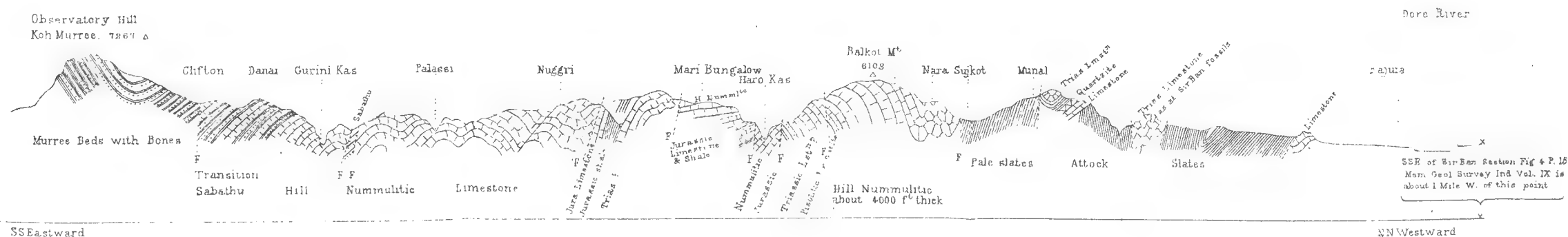
- Superficial River deposits &c
- Lower Tertiary Sandstone clay limestone &c
- Eocene limestone and shale
- Cretaceous limestone
- Jurassic limestone shale &c
- Trias. limestone dolomite &c
- Tanol group: quartzite &c
- Limestone dolomite &c
- Slates
- Schists
- Limestone, dolomite
- Gneiss.
- Trap

* Fossil localities

N° 4 SECTION ACROSS TANOL GROUP FROM MIANKAKHI VALLEY TO BAHINGRA GNEISS 22 MILES.

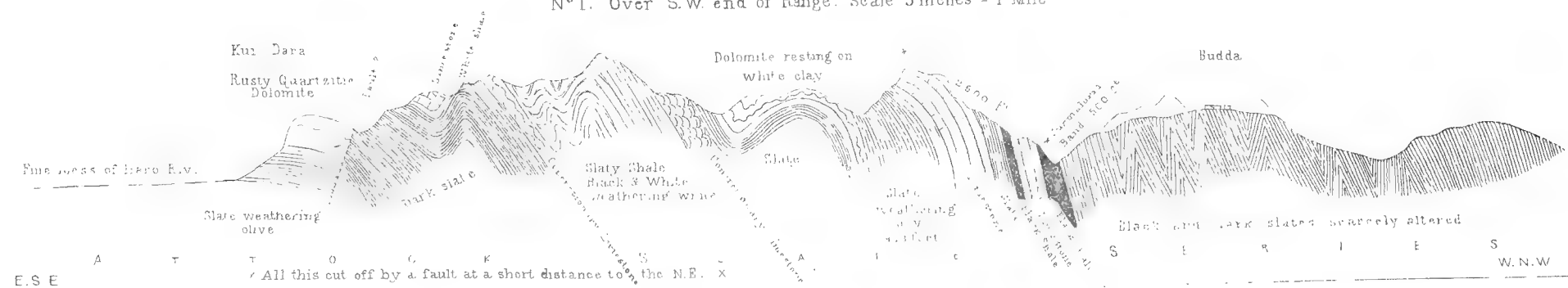
Scales Horizontal $\frac{1}{2}$ Inch = 1 Mile Vertical $\frac{1}{2}$ Inch = 3000 Feet

N° 5 SECTION FROM MURREE VIA MARI TO THE RIVER DORE IN HAZARA 15 MILES.

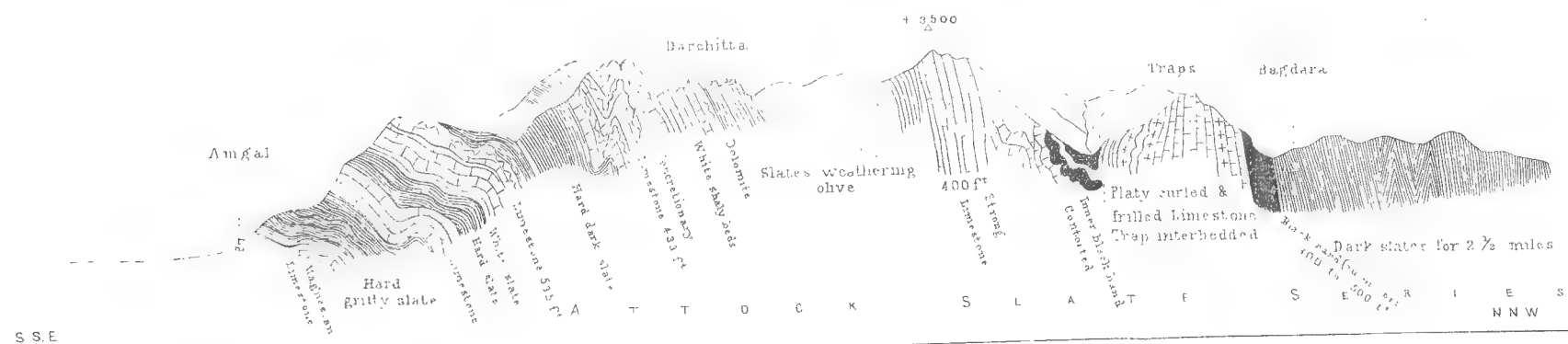
Scales Horizontal $\frac{1}{2}$ Inch = 1 Mile Vertical $\frac{1}{2}$ Inch = 3000 Feet

SECTIONS ACROSS GANDGARH

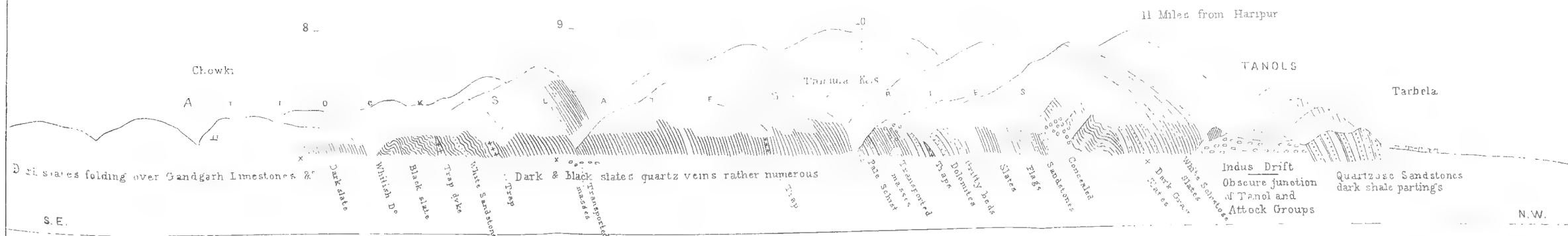
N°1. Over S.W. end of Range. Scale 3 Inches = 1 Mile



N°2. Across Gandgarh at Darchitta. Scale as above.



N°3 Across NE end of Range along left bank of the R. Sirun. thickness 11,691 feet. Scales hor 2 in = 1 mile. Vert. lin = 4000 ft



the action of ice, nor could I see any remains of a moraine in the vicinity. Indeed, these latter evidences of glacial agency have never presented themselves to notice in any part of Hazára I have as yet seen, though Mr. Theobald informs me he has found glacial striæ on one of the large fragments of quartzite, a short way below Turbela. Quartzite of the Tanol group occurs in the immediate locality, but it would be next to impossible to identify one of the stream blocks with the rock of the vicinity, or to prove the former existence of a glacier at the spot from the existence of striation under such circumstances.

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F. V. HAYDEN, Esq.

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ON THE GEOLOGICAL FEATURES OF THE NORTHERN PART OF MADURA DISTRICT, THE PUDUKOTAI STATE, AND THE SOUTHERN PARTS OF THE TANJORE AND TRICHINOPOLY DISTRICTS INCLUDED WITHIN THE LIMITS OF SHEET 80 OF THE INDIAN ATLAS, by R. BRUCE FOOTE, F.G.S., *Geological Survey of India.*

I.—INTRODUCTORY.

THE country to be noticed in the following pages belongs partly to the Madura, Tanjore and Trichinopoly districts, partly to the native state of Pudukotai (Poodoocottah) or Tondiman. Topographically this region may be described as a gently undulating inclined plane rising very slowly westward from the delta of the Cauvery, or the sea board. It is only in the western part that the surface is broken by a few low but steep hills rising in the gneissic area, and by the lines of scarp corresponding generally with the western boundary of the lateritic formations, which occupy by far the greater part of the country now under consideration.

The hydrology of this area is of very simple character, all the drainage falling in a general south-easterly direction into the section of the Bay of Bengal known as Palk's Bay, by eight principal streams. These streams are, with one exception, quite of small size, the exception being the Vaigai (Vygar) which drains the central part of Madura district. Of the others the two most northerly are really branches of the Cauvery proper; they are the Kori-ár (Coray-aur) and Pámáni-ár (Pau-maney-aur), the former running parallel with, but a little distance from, the western boundary of the southern part of the delta, the latter flowing partly just within the delta, and partly within the lateritic area, this latter part of its course being apparently of artificial origin.

The Ikani-ár (Icauney-aur) which falls into the bay to the south-west of Adrampatam rises in the Trichinopoly district, close to Illipur, has a course of only about fifty miles, and is rather torrent-like in its behaviour in wet seasons.

The Vellár (Vellaur) which rises among the hills west of the Trichinopoly-Madura road, in Lat. $9^{\circ} 25'$ and Long. $78^{\circ} 20'$, is also very torrential in its character, rising suddenly in high freshes of short duration which cut away the banks or excavate side channels. According to the map (sheet 80 of the Indian Atlas), the Vellár forks, near the coast, into two branches, represented as of equal size, the northern branch being known as the Narasinga Cauvery. How the topographical surveyors came to show this phenomenon is hard to understand, for it does not exist in nature. The northern branch does not occur as shown, the so-called Narasinga Cauvery being in reality nothing more than an insignificant irrigation channel of such small dimensions that I crossed it repeatedly near Arrantangy without noticing it, though I was looking for it. The southern branch shown in the map is a genuine river, 200 to 300 yards wide and of considerable depth at flood times. Like the other rivers, in this region the Vellár proper flows in a distinctly marked alluvial valley, while the Narasinga Cauvery channel leaves the alluvium immediately below its head, and traverses an unaltered tract of lateritic sand till it reaches the coast alluvium.

Next comes the Pambár (Paumben-aur), which rises to the west of Trimiam (Tirmium) in Pudukotai.

Of the three remaining streams, the Manimut-ár,¹ or Tripatur river, the Serruvayal (Hoop-aur of sheet 80), and the Vaigai, only small portions of their courses lie within our area. The Manimut-ár gathers the drainage of the eastern end of the Sirumallai, a considerable mountain lying to the north-by-east of Madura, and of the hills lying north of Nottam in Madura and Trichinopoly districts. The Serruvayal rises on the high ground east of the Trichinopoly-Madura road near Melur (Mailore), and the Vaigai (Vygañ) takes its origin at the head of the great Cambam valley on the eastern side of the Southern Ghâts. The headwaters of the Vaigai drain only the eastern scarp of the ghâts which receives but a very limited supply of rain, the watershed of the whole mountain mass lying in this quarter along the easternmost ridge, hence the river is of much less volume and importance than might be expected.²

The geological structure of the area here treated of is as simple as its topographical features, all the rocks met with being referable to but six divisions, which are here given in their descending order:—

Geological formations met with.

6. Soils and subaërial formations.
5. Alluvial formations, marine and fluvatile.
4. Lateritic conglomerates, gravels and sands.
3. Cuddalore sandstones, grits and conglomerates.
2. Upper Gondwána beds. Hard mottled shales.
1. Gneissic or metamorphic rocks.

¹ The name Vershalay-aur given to the Tripatur river on sheet 80 is not recognized by the natives for the upper or middle part of the course. They all call it the Manimut-ár.

² A noble project for turning into the Vaigai the surplus waters of one of the principal rivers now flowing to waste in the Cochin backwater has been long and earnestly recommended by the Madras engineers. As the south-west monsoon rains never fail completely on the higher ridges of the ghâts, this project of throwing a vast supply of water across the present watershed would, if carried out, confer an immense boon upon the hot and now too often drought-stricken plains of the Madura country.

The gneissic rocks occupy the western part of the area to be described, and form the highest prominences in it. Amongst them are the line of hills stretching from south of Kolatur (Colatoor), south-south-westward to the Pudukotai-Illipur road, near Annavassal; and several small granite gneiss hills to the south of the Vellár, at and near Trimiam. Between the valley of the Manimut-ár and that of the Vaigai at Madura, a number of hills of small height, but often of very striking outline, occur dotted about at no great distance from the eastern boundary of the gneissic area. Between these hills the general surface of the gneiss country is gently undulating.

A considerable part of the surface of the gneissic rocks is occupied by debris of the younger overlying rocks, which have been in greatest part destroyed by the denuding agency of atmospheric forces.

The rocks assigned to the Rájmahál section of the Upper Gondwána system are very slightly exposed, and their contact with the gneiss was not visible, but there is no reason from the analogy of other parts of the Coromandel coast to imagine that their base rests on anything else than the gneiss.

The Cuddalore sandstones and grits rest, wherever their base is exposed, on the irregular surface of the gneissic rocks, and are themselves overlaid by lateritic conglomerates, gravels and sands, the relations between the two being extremely obscure from the great petrological similarity of two of the principal members of either group, and from the exceedingly limited number and unsatisfactory character of the sections in which the two series are exposed in juxtaposition.

The total absence of organic remains from both series greatly increases the difficulty of dealing with them. The unconformity of the two groups is inferred from the extensive overlap of the younger of the two. The stratigraphical phenomenon of overlap generally involves unconformity between the formations affected by it, but no positive physical necessity exists that there should be such unconformity in every case, and I have been often strongly tempted to think that in this region it is a case of non-proven. Only one section was seen in which unconformity could be demonstrated, and in several of the best sections there is a passing of true mottled grits, which may belong to either group, into lateritic conglomerates of the most typical character, instances of which will be adduced further on.

The Cuddalore conglomerates, sandstones, &c., appear to be the lower part of one formation; the lateritic conglomerates (mostly), gravels and sands the upper part of one and the same group of rocks; mottled grits of both ages apparently lying in between.

The conglomeratic beds of both groups occur in the western¹ parts of the areas, and generally close to the boundary, at which they are mostly well displayed.

The gravelly and sandy members of the lateritic group occupy the eastern part of the slope, and sink in most cases very gently below the delta of the Cauvery, or the coast alluvium.

¹ North of our area the conglomerated forms are best seen along the northern boundary of the formation between Vellam and Tanjore.

The lateritic area is divided by the alluvial valleys of the several rivers above enumerated into various patches, of which the most northerly are by far the largest in area. These patches will be found described and named further on.

Of the alluvia there is very little to say. Only a strip of the southern part of the Cauvery delta was examined. The marine alluvium forms but a very narrow belt in the Adrampatam¹ corner, and the river alluvia are of no great extent or importance. Owing to the great extent of wet cultivation carried on along the various rivers and under tanks constructed across their tributaries, the apparent area of the alluvium has, in the course of many centuries, been largely increased by the formation of artificial alluvial spreads, the boundaries between which and the true alluvia it is in very many, if not in most, cases impossible to determine with any accuracy.

The several rock groups will be most conveniently studied by taking them in ascending order.

II.--THE GNEISSIC OR METAMORPHIC ROCKS.

The prevalent form of gneiss in this region is quartzo-felspathic micaceous granitoid or semi-granitoid gneiss, of pinkish or greyish-pink colour. In texture it varies from a massive, coarse, highly granitoid rock to a schistose gneiss nearly akin to mica schist. A very marked variety which is of common occurrence is a coarse granular quartz rock very rudely bedded and showing numerous small indistinct cavities from which some mineral has been weathered out. In some cases these cavities are filled with an earthy form of dark red or brown hæmatite. The cavities lie in the planes of lamination (coinciding with the bedding), and indeed but for the cavities the lamination would not be visible in most cases. The mass of the quartz is in places not unfrequently very translucent and vitreous in texture.

Hornblendic varieties of gneiss are very much less common in this region, and talcose or chloritic schists were nowhere observed. Ferruginous schists are extremely rare; no example of hæmatite schist was met with, and only one example of magnetite schist.

Finely banded granite gneiss of dense grain occurs here and there largely, as at Tirkornum, west of Pudukotai, and at Ammachattram on the Trichinopoly road.

The line of hills already referred to (page 143) which cuts the Trichinopoly road south of Kolatur, and forms the Alurruttimallai² and Nartthamallai, consists of banded slightly hornblendic granite gneiss of pale grey color weathering to pale dirty flesh color, and showing characteristic bare rocky masses. Tors are not remarkable, or abundant, but there is much weathering along the lines of

¹ Properly the name of this place should be called Adivira-rana-patnam.

² The Alurrutti Mallai or "Man-rolling hill" obtained its name from the practice adopted in former times of executing criminals by rolling them over the great precipice on the south side of the hill. The hill is about 400 feet in height, and the upper part of the great south scarp overhangs slightly.

outcrop and along the plane of an important joint occupying a nearly horizontal position, giving rise to numerous low caves and rock-shelters which are yet used for various purposes by the field labourers. The basset edge of the bedding coincides with the run of the hills, and the dip is westerly. A good specimen of a rock-cut Hindu temple is to be seen on the east side of Narthamallai, and near it are some large holes, now full of water, formed apparently by the weathering out of lenticular masses of more perishable rock.

* The Annavassel hills are of very similar petrological character, and so also is the bold rocky mass of the Kudumimallai (Kodemeahmallai), four miles further to the south-west, so called by the natives from a fancied resemblance to the lock of hair worn by orthodox Hindus at the back of their heads.

These hills are almost bare of vegetation owing to their very rocky character, but to the east of Narthamallai is a ridge of the highly crystalline quartzose rock above mentioned, which crumbles by weathering into a coarse grit thickly covered by heavy thorny scrub. Very little rock is to be seen here, and the contrast between the two ridges is very marked. The bedding of this quartzose rock is very obscure, but still traceable by the lines of hæmatitic grains which form discontinuous laminæ. A precisely similar rock, probably the extension of the same bed, is to be seen a little south-east of Pilliur (Pilleoor), eleven miles to the north-east-by-north. No other minerals could be traced in this rock. This band of granular quartzose gneiss shows also strongly to the east of the Annavassel hill, and is doubtless connected with more southerly outcrop of similar rock, as, for example, that on the south bank of the Vellâr, close to Kemanur. Still further south this very peculiar variety of gneiss occurs largely, and forms several low hills and ridges which, though nowhere of any height, are yet conspicuous from their light color where not covered by jungle, or from their being crested by narrow ridges of bold blocks and tors. Among these the following are noteworthy: the Neddammurum hill, three miles north-east of Tripatur, the Manmallai (Munmullay), the north-eastern extremity of a long low ridge which crosses the Tripatur-Sivaganga high road, and may be traced for some thirteen miles to the west-south-west. This, which in parts is crested by a row of striking tors, forms for a distance of fully ten miles a perfectly straight boundary line on which the western edge of the Sivaganga (Shevagunga) lateritic patch abuts.

Another ridge, about 250 feet high and three miles long, lies between two and three miles north-west of the Manmallai, and is locally known as the Yerimallai. In both these ridges the beds have a very high westerly dip, ranging from 75° to nearly, if not absolutely, vertical. Very similar to both these ridges is another which abuts on the left bank of the Vaigai river, about four miles south-east of the town of Madura, and which extends east-north-east towards and apparently joins the row of huge tors which culminates in the Trivadur trigonometrical station hill. Besides the outcrops of the granular quartzose gneiss above mentioned three other occurrences of it should be noted; these are a band occurring about two and a half miles east of Tripatur, which is possibly a continuation of the Neddammurum beds before referred to. The gneissic rock seen in the inlier south of Trimiem is a similar granular quartzose variety, the crest of a basset edge from which the overlying laterite has been denuded.

Unconnected with any of the above beds is a band of the granular rock at Mallampatti (Mullumputty), forming a low rocky ridge. The bedding in this case is extremely obscure and doubtful.

A great show of beautifully banded micaceous granite gneiss is to be seen at Virallimallai, a bold rock crowned with a temple of some note about twenty miles south-west of Trichinopoly on the high road to Madura. The lamination is in parts greatly contorted and "vandyked," and the pink color of the rock, banded with shades of grey and occasional black micaceous laminae, forms a stone of striking beauty. A similar banded, but paler colored hornblendic granite gneiss is very largely quarried at Puliarpathi (Pooliarputty), four and half miles east of Tripatur. The rock here has, however, undergone much less contortion, and the beds run in a simple ridge coinciding with the strike. These beds appear to underlie the granular quartzose beds which form the Neddammurum hills above referred to.

Among the more noteworthy outcrops of granite gneiss in the northern part of our area is a band of a pale grey micaceous variety which forms some large tors and bosses at Killumallai (Killumalla) in the northern corner of the bay of gneiss north of the Ikani-ár (Icunney-aur) valley. The general surface of the gneiss in this bay and south of it nearer Pudukotai is much obscured by sandy semi-lateritic soil. Gneiss crops up only here and there, and mostly in detached rounded bosses or "whale backs," as *e. g.*, by the Konanda Kovil bosses, and the extensive "whale backs" north-west of Shembatur.

The rock forming the Vellengoody and Kunamulla trigonometrical stations lying a little westward of the gneissic bay just referred to, and the bosses of gneiss north of Kirnur (close to Kolatur) consist also of micaceous granite gneiss distinctly bedded, especially in the former case. There the bedding is greatly crumpled, and the rock weathers of dirty pinkish color. The Kunamulla rock is more compact, less micaceous and paler in color. It is quarried, and the freshly broken rock is very handsome, banded with pale shades of bluish and whitish-grey.

Where the gneiss has been directly overlaid by the conglomerates and laterites of the younger series, it mostly shows a great deal of yellowish-red (rusty) ferruginous staining and a peculiar and characteristic gritty roughness of decomposition of the surface not seen where the weathering action has taken place on the long exposed surface.

Other fine outcrops of granite gneiss occur at Suriur (Sooriore) on the boundary of the laterite about seven miles north of Kolatur, and to the west of the last place to the north and south of Nangupatti (Naungooputty), and at Shatanpatti and Rapussel (Raupoossel). There are also numerous fine examples of granite gneiss rocks to be seen on either side of the Vellár valley to the westward of Tirkornum, *e. g.*, at Permanad, Chittur (Shittoor), and Surramulla. West of the latter village is a superb tor of great height, a conspicuous object from considerable distances. East of the village several ridges of gneiss cross the river and divide the alluvial basin into two parts. The high ground south of this near Kotur is crowned by several prominent bosses standing up out of the scrub jungle.

In the southern part of our area several noteworthy ridges of granite gneiss occur, *e. g.*, at and to the north-east of Kilavaladu (Keelaladoo), also at Melur, and last but not least in size or in striking appearance is the ridge known as the Anaimallai (Annamulla) or Elephant hill, five miles north-east of Madura. This last ridge terminates at its southern extremity in a very bold bluff, bearing when seen from various points a very fair resemblance to a huge elephant, a likeness which has given it the name it bears, and connected it with the principal mythology of Madura and the famous temple of Minakshi. It is a perfectly naked rocky ridge, about two miles in length, consisting of grey and pale pink banded micaceous granite gneiss of coarse texture. The dip of the bedding is not distinct; it is, however, mainly westerly, though the northern extremity looks as if it were the remains of an anticlinal fold.

The numerous low rocky hills at and around Trimiem in the southern part of Pudukotai State all consist of coarse, generally micaceous, banded granite gneiss of pale color, varying from pure grey to pinkish or brownish-grey. Tors and great rounded blocks are numerous.

Highly hornblendic gneiss is of rare occurrence in the gneissic area between the Vaigai and the Cauvery; no important beds of it were noted anywhere.

The general strike of the bedding trends from west-south-west to east-north-east on the left bank of the Vaigai river, to north and south, or north-by-west south-by-east, in the neighbourhood of Illipur and near the northern limit of our area as Trichinopoly is approached.

A small tract of country over which the strike has a totally different tendency occupies the centre of our gneissic area, and extends from the valley of the Manimut-ár northward to within a couple of miles of the Pambár valley at Trimiem. In the southern part of this tract the strike varies from east-by-south west-by-north to north-west-by-west south-east-by-east; in the central part no well-bedded rocks were mapped, but in the northern part the strike changes from east-west to east-by-north west-by-south.

Only one occurrence of magnetic iron in the gneiss was met with; this was about a mile north-east of Mallampatti (Mallampatty), a village in the Pudukotai state nineteen miles north-west-by-north of the town of Pudukotai. Very little of the outcrop is seen, but a good deal of debris of a rich magnetite bed is scattered about the fields a little to the eastward of the Mallampatti granular quartzose gneiss ridge above referred to (page 146).

III.—THE UPPER GONDWÁNA SERIES.

Analogy with the geological structure of the more northern parts of the Coromandel coast would suggest as extremely probable the existence south of the Cauvery of representatives of the Upper Gondwána formation; and in fact two outcrops of rocks referable on petrological grounds to that series were discovered underlying the lateritic rocks in Madura district to the north-eastward of Sivaganga. The petrological resemblance of the shales which occur at a small village called Ammersenpatti (not shown in the map) lying near Mudochempatti,

ten miles north-east-by-east of Sivaganga, is very great to some of the hard shales occurring at Sripermatūr and Vamāvaram; but unfortunately no organic remains could be found, though very closely searched for. The shales are not seen *in situ*, but only as material turned over from the bottom of a small tank south of the village. A considerable quantity, however, was exposed in the bank of the tank in clean condition, so that the color and texture of the rock could be well studied. The prevalent colors are buff and yellow mottled with white. Some quantity was also noted of pink color, ranging to red with a crust of white about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness along the lines of jointing, which are sharply cut.

About a mile south-east of this spot I came upon a small opening in the heavy scrub jungle where much debris of very sandy hard shale, almost a sandstone, lay mixed up with lateritic debris; this shale, too, bears a strong resemblance to many sandy shales occurring in the northern outcrops of the Upper Gondwána series. No fossils were here observed, nor was the rock seen *in situ*, the surface at that spot being a dead flat showing no sort of section.¹ The spot where the hard sandy shale was seen is passed through by the cart track leading south-south-eastward to Kalliar Kovil.

The petrological resemblance of these shales to members of Rájmahál group (Upper Gondwánas) in the Trichinopoly, Madras, and Ongole areas is certainly far greater than their resemblance to any member of the lateritic series, or of the Cuddalore sandstone group, that I am acquainted with, but in the absence of organic remains, the age of the Ammersenpatti shales cannot be positively determined.

Very faint traces of drab or buffy shale were noted in the bank of a tank-well on the west side of the road to Tripatūr, about two miles north of Sivaganga. Only small chips of the shale were found in the mass of kankary lateritic gravel turned out, and no traces of fossils could be found.²

Some connection exists also, unless I am mistaken, between some remarkable boulder beds, resting upon the surface of the gneiss in this quarter, and the Rájmahál beds. These boulder beds cover a very considerable surface on the higher ground north-east of Sivaganga, and south-west of Serruvayal. Their limits were not determined owing to the great defects of the map (sheet 80), and to the difficulty of doing any mapping in extensive and thick spreads of scrub jungle in the absence of any landmarks. The boulder beds are best seen along the road leading from Natarashenkottai, north-north-westward to Kolakattipatti (Colacuttyputti). They appear to be due to the action of surf beating on shoals;³ for not only do many large and well-rounded pebbles strew the surface, but the surfaces of various protuberances of

¹ This spot was only examined cursorily, as I came upon it very late in the day when far from camp, and had no subsequent opportunity of revisiting it.

² The country round Sivaganga deserves a closer examination than I could give it, as I was seeking to carry the boundary work southward as fast as possible. Failing health and strength, however, compelled me to seek a change which prevented my revisiting these localities as I intended doing.

³ These boulder beds lie at a higher level than much of the gneissic area to the westward of them.

the coarse granular gneiss are worn and rounded *in situ*. Much coarse and fine lateritic debris rests on and among the boulders. No section was seen showing undisturbed laterite in clear juxtaposition to the boulder beds, but the latter bear greater resemblance to the beds of similar character forming the base of the Rájmahál formations near Utatúr, Sripermatur, and Ongole than they do to any true lateritic conglomerate that I am acquainted with.

IV.—THE CUDDALORE SERIES.

The representatives of the Cuddalore series (established by Mr. H. F. Blanford for certain rocks in South Arcot and Trichinopoly districts) which occur in our limits consist of coarse conglomerates, sandstones and grits, the latter passing locally into a rock perfectly undistinguishable from the common laterite which so largely covers the surface in this region. Here as in so many other parts of the Coromandel coast, the slight slope of the country and the very low dip of the rocks have prevented the formation of really valuable natural sections, and civilization has not yet advanced sufficiently to have given rise to any artificial ones of importance. The extension of wet cultivation greatly militates against the formation of deep channels by the different smaller streams draining the country. All are dammed back at many points of their courses, and give rise to the formation of local alluvial flats which only add to the obscuration of the younger rocks, whose relations are therefore generally very unsatisfactorily and imperfectly displayed, so that definite information regarding many interesting stratigraphical points is at present not procurable. The total absence, so far, of organic remains renders the correlation of detached exposures of even similar rocks of great and inevitable uncertainty. These difficulties present themselves saliently in the Tanjore, Pudukotai, and Madura districts.

The most northerly section in which rocks, assumedly of Cuddalore age, are to be seen, occurs to the south-east of the village of Thachenkurichi (Thachencoorchy), some six miles north of Gandarakotai (Gundaracottah) in Tanjore district. A fair show of grits and sandstones is here to be seen along the sides of a small winding stream. The sandstones occur in irregular somewhat lenticular patches of dark brown color and considerable hardness. They are overlaid by gritty sandstones mottled pale purple, yellow and rusty red. The upper beds of these are very clayey and lateritic in character. To the south-east of this section lie two small low hills, both capped with thick conglomeratic laterite, but no evidence could be found as to what underlies this capping, the sides of the hills being thickly covered with debris and thorny jungle. The sandstone beds in the stream banks and bed roll about in various directions. West of the village is a broad low ridge of ill-compacted gritty shingle conglomerate, which dips eastward under gritty laterite close to the high road to Pattukotai. Similar conglomerate occurs resting on the gneiss on the high ground north-east of Pudukotai near Kumupatti (Coomooputti), and further west near Yeddiapatti.

Along the southern brow of the same high ground overlooking the town of Pudukotai is a line of low cliffs, 12 to 16 feet high, showing conglomerate of

quartz and gneiss pebbles in a gritty, often semi-lateritic, matrix of reddish purple, color, and containing here and there small nests of clay. This conglomerate, which is not very hard, rests on the very irregular surface of the banded (slightly hornblende) granite gneiss, to which it has imparted a strong yellow stain.

Among the more southerly conglomerate beds are those met with in the Shenkarai ridge, about eight miles south-by-east of Pudukotai. They are displayed on the western slope opposite Shenkarai village by an extensive series of rain gullies which expose a considerable surface of the gritty conglomerate; but unfortunately do not cut deeply into it. Its base is not seen, but it probably rests directly on the gneiss which shows in Shenkarai tank. The bedding is seen to dip east-north-east or east-by-north at angles of from 12° to 15° . False bedding prevails, but only to a small extent, for so coarse a rock. The conglomerate is of mottled brown to pinkish and whitish, less frequently reddish-yellow color, and tolerably compact with a gritty matrix, including quartz and gneiss shingle, from the size of a cocoanut downward, in moderate quantity. The eastern slope of the ridge¹ is overlaid by the most massive and continuous (sheet-like) bed of lateritic conglomerate that I have seen on the Coromandel coast; it covers a considerable space between Arimullum (Aurmoolum) and Malalapatti, and is itself lost sight of to the east under lateritic sands and the alluvium of the Vellár.

Further eastward, away from the boundary, the conglomeratic character of these Cuddalore beds diminishes rapidly, and very few sections are to be found that penetrate the surface laterite. Where the sub-rock is reached, it is seen to be a grit or sandstone.

A second section of the Cuddalore beds forming the Shenkarai ridge was found in the scrub jungle about two miles further south-west and about a mile south-east of Ayangudi. The beds here seen are unlike the Shenkarai beds, they are conglomerates of very coarse texture and rather friable. The matrix, which varies from light red to brown red in color, is semi-lateritic and vermicularly cellular to some extent. The enclosed shingle is mostly large and well rounded; it is chiefly quartzose and all apparently of gneissic origin. The lowest bed seen is mottled and more gritty in texture with fewer enclosed pebbles. The dip is southerly at low angles. Here as at Shenkarai the section penetrates but a few feet vertically.

A section in which gritty sandstones are seen peeping out below the surface laterite occurs close to Ammagudi (Aumagoodey) on the left side of the Vellár valley, some four miles north-west of Arrantangy. Brown and purple sandstones occur here of sufficient hardness locally to be quarried into coarse flags. They are exposed in the gentle scarp below the laterite.

The last outcrop but one of Cuddalore rocks to be mentioned occurs to the south-east of Sivaganga, about a mile and a half from the town. Here several beds of hard thick-bedded grit crop

¹ The geographical features of this ridge are very inaccurately shown in sheet 80, where it appears of considerable height instead of as a mere low rise scarped only for a short distance at its northern extremity. Extensive scrub jungle covers the greater part of its surface thickly.

out from below the general lateritic covering of the country. In color the rock is dark purplish-grey with brown bandings, and so hard as to be worked by blasting. The beds have a north-easterly dip of about 20° . Much diagonal or "false" bedding is seen in the fresh broken specimens of the rock, which is overlaid conformably to the eastward by less compact dark-brown and yellow-brown grits. The hard grits are largely quarried as building stones. Unfortunately no laterite is seen in juxtaposition with the grits, so the local stratigraphical relations of the two rocks cannot be studied.

The best section of Cuddalore grits of the softer variety occurs about eleven miles north-east from Pudukotai, a little west of the high road to Tanjore. Here the small stream which feeds the Perungalur tank, in descending from the high ground to the north, cuts through the upper laterite beds, and exposes beds of typical grits in many gullies, forming so many miniature canons of very perfect shape with nearly vertical sides, from 12 to 18 feet deep and only 2 or 3 feet apart at the bottom. The grit beds show a rude but distinctly columnar jointing strongly resembling starchy cleavage on a huge scale.

The section here displayed shows the following sequence of beds in descending order:—

4. Black laterite conglomerate, on gravel.
3. Red-brown vermicularly porous conglomerate, passing down into—
2. Brown conglomerate with many pebbles of quartz-grit and older laterite.
1. Grits, pale mottled, generally showing columnar jointing with vermicular tubes and scattered galls of fine clay.

In this section distinct unconformity is seen to exist between Nos. 1 and 2. No signs of organic remains could be traced after very careful search.

A small show of rather soft grit of red and brownish mottled color appears between the boundary of the gneiss and the overlying laterite between Surianpatti (Pothanavial of the Atlas map) and Parembur in the south-western corner of the Tanjore patch.

Mottled grits which on petrological grounds are considered as of Cuddalore age are exposed, in sections of wells and deep tanks, under the laterite conglomerate at Palatur (Pullatoor) and Shuragudi (Shooragoody) in the Shahkotai patch of the lateritic formations (see page 153).

The boulder beds described above (page 148) as occurring to the north-east of Sivaganga may possibly be of Cuddalore age, or tertiary, instead of Rājmahál age, or secondary, as there is no positive evidence either from the presence of organic remains or speciality of stratigraphical position, but in their facies they are decidedly much more akin to the older series.

V.—THE LATERITIC GROUP.

The Cuddalore series is overlaid by the several members of the lateritic series, which vary from hard typical conglomerates through gritty beds to gravels and finally to reddish sands with variable quantities of gravelly pisolitic hæmatite

concretions. The sandy beds occupy the lower slopes near the delta or the band of marine alluvium bordering the coast, while the conglomeratic beds occupy the higher grounds to the west and often overlap widely on to the gneiss.

The various rivers which convey the drainage of the country to the sea divide the lateritic region into a number of minor areas or patches amounting in all to nine. Their sizes are very unequal as might be expected, ranging as they do from several hundred square miles to only a few dozen or so in extension. Taking them from north-east to south-west the first is the *Tanjore patch*, so called from the fact of its being the southward continuation of the great patch, on the northern edge of which stands the famous old town of Tanjore, five miles beyond the northern limit of the map. This is followed southward of the Ikani-ár by the *Pudukotai patch*, which is divided by the Vellár from the *Shenkarai patch*. South of the Pamb-ár lies another patch of laterite which I will designate as the *Sháhkotai* (Shawcotta) *patch*. South of the Manimut-ár is a small patch which may conveniently be called the *Serrucayal patch*. The most southerly spread of lateritic rocks to be described lies around Sivaganga and should be named accordingly the *Sivaganga patch*. Two of the remaining patches to be considered lie to the westward of the general run of the patches close to the town of Tripatur, after which they may be suitably called the *north* and *south Tripatur patches*. The ninth and last patch lies at the western extremity of the Tanjore patch on the border of the country included in sheet 79; it may for convenience be called the *Nallur patch*. A great number of little patches too minute to be mapped are dotted over the gneiss area at various distances from the present laterite boundary, showing that its former westward extension was considerably greater than it is at present, and that great part of the original deposits has been removed by denudation. Some of the smaller of the far outlying patches have undergone so much change from weathering and reconsolidation that they might almost be reckoned as subaërial formations.

The most remarkable spreads of conglomeratic laterite are to be seen along the western boundary of the areas in nearly every case, but only a few of them need be specially mentioned. To begin with the Tanjore patch. Vast sheets of laterite conglomerate are to be seen to the west and south of Gandarakotai. A little to the north of Suriam-patti¹ especially the bare black sheets of rock arranged in terraces with low steps give the country a strange appearance. Where the conglomerate is covered with soil the latter is generally a very hard compact sandy clay of red or yellow (bath-brick) color much marked by sun-cracks, which run in very regular systems and give the soil a tessellated appearance on a large scale. In the presence of water these lateritic soils are fertile, but the high dry downs they are oftenest seen upon are generally waste, and bear but little else than a very low scrub of *Dodonæa viscosa* mixed with a few dwarf *Mimosæ*.

This low *Dodonæa* scrub is quite a feature of the hard lateritic soil tracts, and many instances of it might be adduced. The yellow soil especially assumes

¹ Pothanavial of Atlas map.

not unfrequently very much the appearance of a gritty sandstone without, however, actually possessing sufficient cohesion to deserve the name of rock, though in some cases it very nearly merits being so called. A good example of this may be seen at Nadduvaykotai, four miles west of Pattukotai (Puttucottah).

Passing over to the Pudukotai patch striking spreads of hard typical conglomerate are to be seen in many places near the western boundary and even at some miles distance from it, *e. g.*, at Urriur in the extreme north-west corner of the patch, also nearly all along the left side of the Vellár alluvium valley close down to Arrantangy, and to the north and north-west of Alangudi (Aulangoody).

The Shenkarai patch contains, as already mentioned above (p. 150), an extensive and massive development of conglomerate in the eastern slope of the Shenkarai ridge and the plain east of it. This great development of conglomerate is continued under the alluvium of the Pambi-ár and re-appears in the Shahkotai patch and is specially well seen at Kilanellikotai (Keelnellicottah),

where the walls of the extensive old poligar fort are built of the massive laterite quarried close by. The conglomerate is also admirably seen on the bluff east of Neddengoody, which may be regarded as the continuation of the Shenkarai ridge south-westward. From this bluff which is crowned by a picturesque temple called the Padikása Nadar Kovil, the ridge declines and is lost to the south-west in a high-lying plain of massive laterite extending without a break to Palattoor (Pullattoor). The high ground between Shuragudi (Shooragoody) and Káragudi (Caurgoody) is also covered by a vast sheet of laterite conglomerate, as are also the high ground to the west and south-west of Káragudi near Yalengudi and Kutalur (Coothaloor). The conglomerate is mostly very richly ferruginous for a laterite, and there are abundant traces of a once existing active iron smelting industry. Large quantities of iron slag have been scattered about in many places where now no iron is made.

In the Serruvayal patch of lateritic rocks highly ferruginous conglomerate covers a large space between Serruvayal and Kalel (Cullel), also near Páganeri (Pauganary).

In the Sivaganga patch spreads of conglomerate of considerable extent are frequently met with, *e. g.*, to the north-west of the town, to the east around Natarashenkotai, to the north-west of Kalliar Kovil, and in the northern corner of the patch near Wukur and Tiruvenpatti (Tirroovenputty).

In the two patches north and south of Tripatur the dense and highly ferruginous form of the laterite conglomerate is less developed, and a coarse less ferruginous and less compact form, including very large quantities of gneissic shingle, prevails.

The Nallur (Nullor) patch like the westernmost part of the Tanjore patch consists of a more gritty and rather less compact form than prevails over the spreads above enumerated. The rock is perhaps equally ferruginous, but owing to its gritty character shows a

rougher duller surface with many fewer vermicular cavities. The larger enclosed fragments of older rocks, which consist almost entirely of gneissic quartz, are mostly subangular or angular, giving the rock a breccia-like appearance. Well-rounded pebbles do, however, also occur. A conspicuous example of such a breccia-conglomerate is that occurring to the west of Payakudi in the north-western corner of the Tanjore patch.

The outlying patches of laterite conglomerate resting on the gneiss in the northern part of our area agree generally in character with the gritty variety just described, but those in the south-westerly part are of the more typical form with many vermicular cavities in the more clayey mass. The southern patches when very conglomeratic contain chiefly well-rounded water-worn pebbles, and approach in coarseness to some of the typical conglomerates of median texture in the Madras region, in which stone implements occur. Whether stone implements occur in this southern laterite is a question to which a positive answer cannot yet be given, no unquestionable examples having as yet been found. I did, however, find occasional specimens of coarse quartzose stone which bore a resemblance in shape to various forms of chipped implements common in the more northerly gravels and conglomerates, but the material is so coarse that the chipping could not be considered as positively artificial. The most undoubtedly artificial specimen was a broad axe-head found about a mile north-north-west of Shuragudi in the Shahkotai patch. Occasional fragments of chert derived from unknown sources occur scattered sparsely over the surface of the lateritic conglomerates. Three specimens of this chert appear to be of artificial shape, one is a flake of small size resembling an arrow-head, the second a small prismatic core, the third a thick oblong sharp-edged flake with a distinctly serrated edge to one of its longer sides.

Several large leaf-shaped flakes, almost deserving to be called implements, were found by me between Vellam and Tanjore, only a little distance north of the line forming the northern limits of sheet 80. Two of these were adherent to the surface of the conglomerate and appeared to be genuine exposures *in situ*. They had to be hammered out of the rock.

These large flakes appear to be made of a chert identical with that forming the great fossiliferous blocks lying in the mottled grits occurring to the east of the old fort ditch at Vellam.¹ The small implements above mentioned are made of a much more jaspery-looking variety of chert.

I cannot help thinking that closer search of the shingly lateritic beds such as that at Tallakolum (Tullahcolum), north of Madura, and those occupying so large a part of the two Tripatur patches, would lead to the finding of unquestionably recognizable specimens of chipped implements.

Of the very numerous spreads of lateritic gravelly sands which occupy the eastern part of the lateritic area, the most remarkable is that cut through by the Pámani river at and to the south of Manárgudi in Tanjore district, which also extends close down to the sea-coast at Adrampatam.

¹ See Mem. G. S. I., IV, p. 36. A fresh collection of fossils from these chert rocks was made in 1878 to supply, as far as possible, the place of the collection lost on its way to Calcutta by the wreck of the *Aurora* in 1860.

The section of these sands in the bank of the Pámani-ár at Kara-ká-kád (not in the map), a little village about a mile north-east of Painganád (Pynga-Kara-ká-kád section. naud), shows the following succession of beds :—

Local alluvium	...	...	...	1½'—2'
Gritty sands	...	...	...	2'
Ferruginous gravel with quartz fragments	...	...	...	4' (exposed).

The gravel is formed by accretion of quartz grains (sand) with a brown hæmatitic cement into rudely rounded lumps generally about the size of a hazelnut. These lumps are here, and generally in the eastern part of the lateritic area, unglazed and dull in appearance; further west, however, the lateritic gravel is generally glazed and externally smooth even when fracture shows the interior to be gritty. The shiny glazed form is also seen in the lateritic sands of this part of the country, and a half glazed form is not uncommon.

Where bare or but thinly covered with vegetation, the surface of the bands is often covered by thin sheets of this ferruginous gravel, from which the sandy and clayey portions of the original bed have been removed by fluvial action. Where the thickness of the gravel beds has become considerable, subaëreal consolidation not unfrequently sets up, specially where the glazed form of the gravel occurs.

In the northernmost part of the Tanjore area within sheet 80, in the tract lying along the high road from Tanjore to Adrampatam, the lateritic sands are seen to pass down into typical soft grits of pale color containing but little ferruginous matter. These grits may be seen at the villages of Kovilur (Coviloor), Karkan-kotai (Curkancottah), and Ulur (Woolnoor). The sections, which are only in the sides of wells, are neither deep nor clear enough to show the relations of this pale grit with the undoubted Cuddalore beds.

The whole of the eastern part of the lateritic area is not everywhere covered by sandy beds : some considerable tracts, e.g., around Pattukotai (Puttucottah) are occupied by rather hard red loam containing variable and sometimes considerable quantities of lateritic gravel of the non-gritty glazed variety. This hard red loam graduates into the sandy form imperceptibly. It is generally confined to the higher grounds.

The bottoms of the shallow valleys which drain the area occupied by the softer members of the lateritic series are frequently occupied by swampy ground or by small quicksands, very unpleasant to a guideless rider, and the higher parts are not unfrequently very sandy.

The flora of the lateritic area differs in the eastern parts considerably from that of the gneissic region and of the high-lying area covered with hard conglomerate or quasi-baked clayey soils. The sandy eastern parts support very extensive plantations of cashew-nut trees (*Anacardium occidentale*), with very frequent clumps of bamboo and pandanus. *Calophyllum inophyllum* occurs also more frequently here than in any other parts of Coromandel coast that I am acquainted with. The jack tree (*Artocarpus*

nitigrifolium) is also cultivated to a very great extent all over the lateritic area, but some of these trees are common on the gneissic area.

Of minute plants one of the most characteristic, which occurs in immense numbers in low lying damp sandy flats, is a small *Drosera* or sundew, though elsewhere a very rare plant in the low country. A zoological peculiarity of the lateritic sandy region is the great frequency of a large *Spongilla*, or freshwater sponge, in many of the shallow rain-fed irrigation tanks. Nowhere else have I noticed this sponge to be common or to attain to anything like the size it does in this quarter.

Alluvial Formations.—The alluvial deposits coming within the scope of this paper are of small extent, as only a small section of the south-western corner of the Cauvery delta was examined, and the alluvia of the various small rivers traversing our area are very limited.

The western part of the Cauvery alluvium is formed of a black clay, apparently a true regur, becoming gradually sandy as the sea is approached. No section penetrating through this black clay was seen within the limits of sheet 80, but a fresh excavation for the foundations of a new sluice branching off from the Pamani-ár just within the area of sheet 79, on the road from Manárgudi to Neddamangalam railway station, revealed a bed of very stiff blue clay full of small kankar (gravelly tufa).

The alluvia of the smaller rivers is generally a whitish mixture of sandy clay with lateritic pellets and small debris of quartz and gneiss. The flats are often slightly swampy, or barren, and unproductive from the saline matters enclosed. An exception to the whitish alluvium is offered by the alluvium of the Manimut-ár below Tripatur, where low cliffs of reddish loam form the river banks for a couple of miles or more above Neddarakotai. The alluvium of the Vaigai appears to be generally sandy, but no sections were seen, and from centuries of wet cultivation the whole surface must be looked upon as really "made ground."

The coast alluvium near Adrampatam is generally clayey near the surface and edged with a narrow strip of ill-defined sandhills. No sections of the coast alluvium were seen.

Soils.—The soils depend almost everywhere on the underlying rocks for their character. Red and reddish sandy soils abound. Black soil is not at all common. It occurs largely only over the western side of the Cauvery delta, and under a few important irrigation tanks where it must be regarded as of artificial origin. Whitish clayey soil very similar to the pale alluvia of the large streams is met with in many valleys of the eastern lateritic areas, and, as above mentioned, often forms small treacherous quicksands most disagreeable to the rider.

Where the conglomeratic laterite occurs two forms of soil prevail, both of them hard clayey sands, the one of bright red, the other of pale yellow (bath-brick) colors—often approaching in texture to true sandstones. Many large spreads of these occur covered with low scrub of *Dodonæa viscosa* and a few dwarf mimosæ and other thorny bushes, *e. g.*, on the high ground to the south of Gandarakotai in the Tanjore patch, and again on the high ground north-east-by-east of Alangudi in the Pudukotai patch. The surface of the soils is

often covered with light wreaths of grit and sand collected by the prevailing winds.

The red soil is the more common form, but both it and the yellow variety show frequently on the hardest parts of the surface a semi-metallic-looking blush of bluish-black color.

Over the lateritic bands the soil is generally a nearly pure, less frequently somewhat clayey, sand.

Real blown sands were very rarely noted within the limits of sheet 80 as far as the survey extended; those in the little strip of coast examined in the Adrampatam corner of Palk's bay are hardly worth noticing, and the same may be said of a few low hillocks on the bank of the Vaigai river near Tirupavanam (Trippawanum). The most notable accumulation of sand raised by wind was seen between Vadakur (Vuddacoor) and Pinneyur, three and half miles south-west of Ortenád Chattram (Mootooaumaalpooram of the Atlas map). The hillocks here are of very small extent, but rise from 15 to 16 feet in height; they are limited to a very small superficial area.

Economic Geology.—Few districts even in the poor region of Southern India are so extremely destitute of valuable minerals as the country dealt with in these pages. Building-stones, road-metal, and kankar for lime-burning are at present about all the material collected for economic purposes, with the exception of a little impure salt and saltpetre.

Iron used to be smelted in some quantity from ores obtained from the lateritic conglomerate beds as testified by the quantities of iron slag scattered over the country and here and there accumulated in large heaps. Of late, however, this industry seems to have died out entirely, for I could not hear of its being now followed anywhere, nor did I come across any villages in which smelting furnaces were still in operation.

The compact richly ferruginous laterite conglomerate furnishes endless material for rough building purposes, and is even carefully cut and dressed for better class buildings now put up at various places by the rich Natukotai Chetties, a caste of rich traders and soucars who are buying up much land in many villages on the lateritic area and building palatial houses in every direction, besides tanks and temples. Many old buildings of importance have been built of this stone, *e. g.*, the great fort at Kilanelikotai and the fort at Arrantangy. The laterite of the Shenkarai patch and the northern part of the Shahrkotai patch yields the largest and apparently the most reliable and homogeneous blocks I have seen quarried anywhere between Cape Comorin and the Kistna river.

Of gneissic rocks the Puliarputti banded gneiss is the most largely used. The great quarries four miles east of Tripatur are largely worked for blocks of all sizes, up to nearly 30 feet in length. The stone is in great demand because of its beauty and moderate price owing to its being easily quarriable. Large pillars about 12' by 3' by 1' 6" roughly dressed for the gates of pagodas or mantapams cost only Rs. 30 on the spot.

Very handsome granite gneiss is quarried at Tirkonum, west of Pudukotai, and at Kunamulla trigonometrical station hill, fourteen miles to the north. The granite gneiss at Virallimallai, twenty miles south-west of Trichinopoly

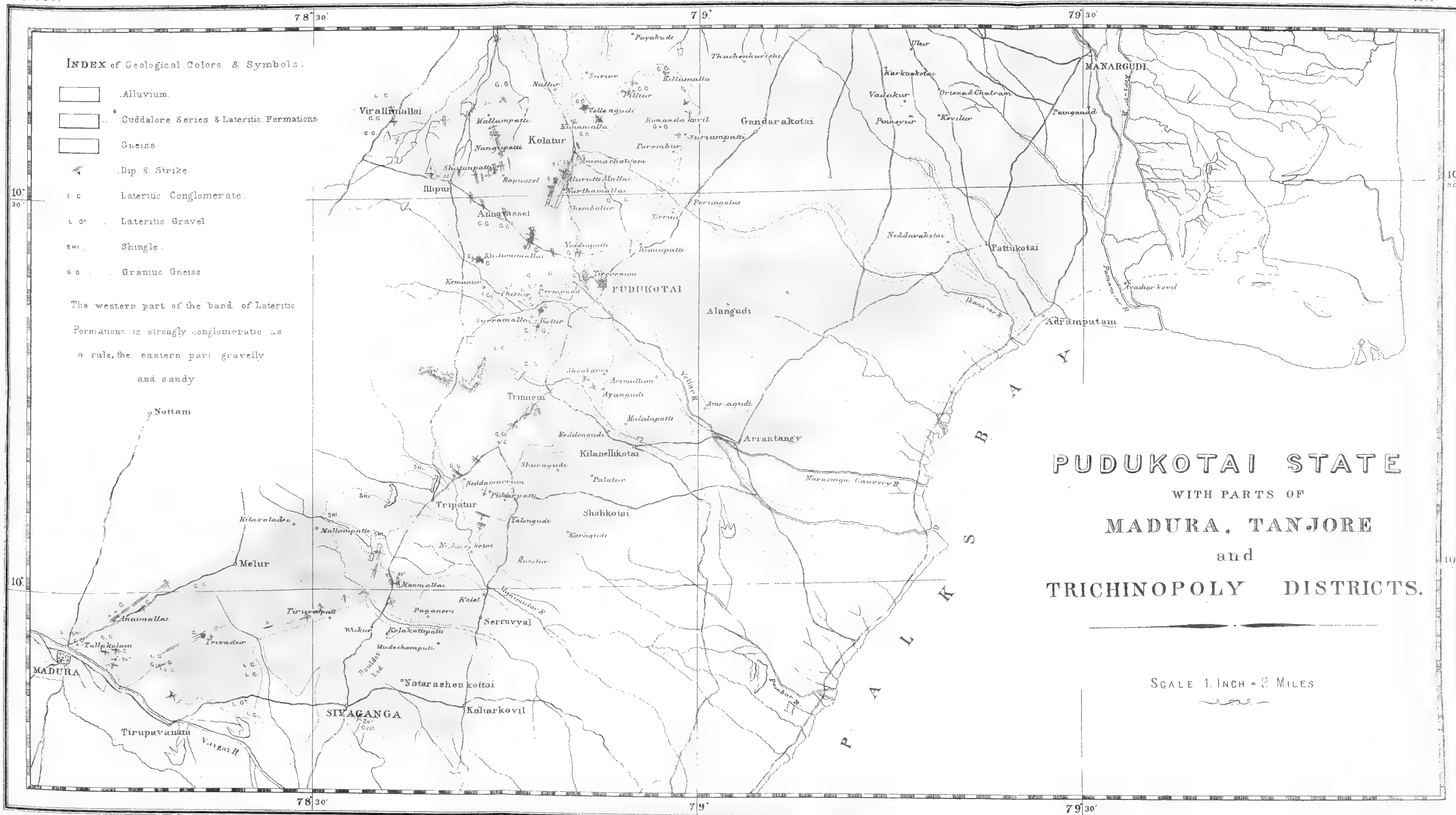
on the Madura road, could yield stone of very great beauty if required (p. 146). Less handsome, but very useful stone is quarried from the granite gneiss rocks occurring at Trimem in Pudukotai State, and at foot of the Anaimallai near Madura (p. 147).

My stay at Madura was too limited to allow of any enquiry into the question of the localities which yielded the splendid black hornblendic rock forming the noble pillars to be seen in Trimal Naik's palace, one of the most remarkable buildings in India. The quarries which yielded this stone and the hornblendic rock carved into the many bold striking figures and statues in and about the great Madura pagoda were not among those seen by me, and doubtless lie beyond the limits of the gneissic area surveyed.

Some of the finest and boldest carvings, both of statues and scroll work that can be met with in Southern India, are to be seen at the Avadiar Kovil, or temple, in the southernmost corner of Tanjore district. The great mantapam in front of the temple gate is an architectural work of great beauty and noble proportions, far better worth photographic illustration than many other buildings that have been made known to the public. Unfortunately it is so much off the beaten track that very few know of it, and hardly any one visits it. The stone used is said to have been brought from Trimem and Tirkorum, but is more hornblendic than any of the rocks seen at those places.

The great temple at Manárgudi, on the western edge of the Cauvery delta, is largely built of gneiss from an unknown locality, but which must have been brought a distance of fully fifty miles, supposing it to have come from the very nearest quarries, those of Mammallai, eight miles east-south-east of Trichinopoly. These quarries may well have yielded all the slightly hornblendic pale stone used at Manárgudi and also at the great Tanjore temple, excepting, probably, the famous great bull and a few other large monoliths of much more hornblendic character. It is not known for certain where these were quarried, but I suspect they came from a bed of very hornblendic gneiss at foot of the Pachamallais near Perambalur in Trichinopoly district. My reason for suspecting this is, that when at Tirumanur in 1878, on the left bank of the Coleroon to the north of Tanjore, I saw several very fine monolithic blocks of dark black hornblendic rock lying on the river bank. These were said to have been brought there by the late Rajah of Tanjore from a quarry close to Perambalur to be used for a temple which was never built. This very black stone much more resembles the black monoliths in Tanjore pagoda than anything yielded by the quarries south of the Cauvery.

Great complaints are made in the southern taluqs of Tanjore district of the want of proper road-metal for the roads in those very sandy regions, but this difficulty might be largely met by screening out the lateritic gravel which occurs in large quantity in the sands in very many localities along the Manárgudi and Adrampatam roads.



ROUGH NOTES ON THE CRETACEOUS FOSSILS FROM TRICHINOPOLY DISTRICT, COLLECTED
IN 1877-78, by R. BRUCE FOOTE, F.G.S., *Geological Survey of India*.

The following notes have reference chiefly to the fossils I collected in 1877 from the Utatúr and Arialúr groups, at Utatúr, Maravatúr, Odium, Arriakúr, and Mallúr, which alone received any careful examination. The fossils from the other localities received as a whole merely cursory inspection while being arranged for numbering. The term "new species" that will be found used here and there implies only that the fossil does not agree with the figures and descriptions of species described by Dr. Stoliczka in the *Palæontologia Indica*.

Sponges.—A special feature of the collection is the large number of sponges it contains as compared with the far larger collection originally made at the time the geological survey of the district was being carried out. Dr. Stoliczka figures only two, which he refers to the genus *Siphonia*.

Among the sponges collected by me are numerous specimens belonging to the very important and characteristically cretaceous family of *Ventriculites*. These were found mostly weathered out of a bed of limestone south-west of Maravatúr (*Loc.* 10), very low down in the Utatúr group. They belong apparently to three species, or varieties, of different form and texture (*e.g.*, Nos. 5, 6, 7, 18–20, 45 and 49). Many show the characteristic network extremely well (*e.g.*, No. 49).

With these *Ventriculites* occurred several specimens belonging to another group (? *Spongites*), showing quite dissimilar texture (Nos. 8 to 14).

The same bed of limestone, which forms a small knoll, yielded a considerable number of other fossils, all of which were collected from a very limited space, only a few dozen square yards in extent. The most numerous of these were spines and plates of *Cidarids*; *Belemnites* were found in considerable numbers; a few small *Ammonites*, with other shells and corals, were also obtained. The large *Pecten* (No. 50) came from another bed rather nearer to Maravatúr.

A numerically much larger number of sponges, of a small cup-shaped group, *Naicolum* "sponge" was obtained from one of the lowest beds of the Utatúr bed." group, exposed at head of a gully opening eastward, a few yards east of the old Madras road, $\frac{3}{4}$ ths of a mile south-south-west of Naicolum (*Loc.* 3). These were found with a great number of other fossils on the weathered outcrop of an argillo-calcareous sandstone. With the cup sponges was one specimen of a mamillated species (No. 278). A large specimen (No. 32) of clavate form was also found weathered out of the same bed, but originally derived without doubt from the coral reef limestone at base of the Utatúr group.

Two other sponges were obtained from the middle part of the Utatúr group exposed north and north-west of Odium (*Loc.* 21). Of these, which are numbered 14 and 15, the latter appears to be a *Siphonia*.

Vertebrate remains.—A number of large vertebræ, apparently reptilian, very like those of *Ichthyosaurus*, were found by me in the clays north-east of Utatúr. Nine out of sixteen lay together, in apposition, when I found them, but were

unfortunately disturbed, before I had time to number them, by an officious collector, in direct contravention of his orders. The others had been washed down the slope of the rain gully in which they were exposed, but they all doubtless belonged to the same individual. I have had no opportunity of comparing them with figures of known *Ichthyosaurus* vertebræ. They are numbered 047—63.

The seven shark's teeth (marked 043) belonged, I believe, to the shark that yielded the large vertebræ Nos. 34—40. They were all found quite close together, weathered out of one of the large earthy ferruginous concretions, at only a short distance from the large reptilian vertebræ.

A novelty among Utatúr fossils is the *Ichthyodorulite* (No. 460).

Mollusca.—The chief novelties are several *Rhyncholites*, or mandibles of Nautili, belonging to two if not to more species. Three of small size, not well preserved, were obtained from the outcrop of the "sponge bed" (Loc. 3). Two others, one large, of rather different form (Nos. 24 and 250) were found in the Utatúr clays. Two other peculiar bodies (O 26 and 27) bearing some resemblance to *Rhyncholites*, but both apparently somewhat broken, were also found in the Utatúr clays.

Embedded in the clay filling the body-chamber of a nautilus from Utatúr is a singular body (No. 23a0), somewhat fruit-like in appearance, that I was unable to determine. I wish to draw special attention to it.

From the same locality (O) came what appears to be a new Belemnite (028) of short squat form and blunt pointed, quite unlike any figured in the *Palæontologia Indica*. It is much the rarest form of all occurring in the Utatúr clays.

The long, thin, sharp pointed Belemnite (No. 31) occurs chiefly in the higher clay beds.

Interesting specimens of Belemnites are numbers 67, 68, and 69 from Odium (Loc. 21), parts of phragmocones, the latter of very large size. No. 70 shows great part of the pro-ostreum.

Among the *Ammonitidæ* No. 88, from Anapadi (Locy. 15), may be a new species, for it does not agree with any of those figured by Stoliczka.

Of the rare form *A. kalika* founded by Stoliczka on a unique specimen from the Arrialúr beds east of Utakoil, a second example (OK 16) was found by me at the same place. It is in good preservation.

Of another rare form, *A. ætra*, based by Dr. Stoliczka on two specimens from Cunum, a third example was procured at the same place. It is a young specimen and unfortunately much broken (20e 55).

An apparently new species of *Turrilites* with very delicate transverse ribbings on the whorls was found by me west of Arrialúr (Loc. A, No. 16).

No. 18 from the same locality would also appear to be a new species of *Baculites*. *Baculites*, unless it be part of a *Ptychoceras*.

Of the *Gasteropoda* that I had time to examine and to compare with Stoliczka's figures in the *Palæontologia Indica*, several, which I enumerate below, appear to differ to a considerable extent, and may very probably be new species or varieties—

Nerinaæ, sp.	.	.	.	.	.	.	Locy. 11 ¹	No. 4
Scala, „	.	.	.	.	.	.	„ A ¹	„ 141
Cancellaria, „	.	.	.	.	.	.	„ „	„ 149
Velutina ?	.	.	.	.	.	.	„ „	„ 150
Sigaretus ?	.	.	.	.	.	.	„ „	„ 150a
Natica, sp.	.	.	.	.	.	.	„ „	„ 151
Cantharidus ?	.	.	.	.	.	.	„ „	„ 156
Thylacodes	.	.	.	.	.	.	„ „	„ 159
Trochactæon ?	.	.	.	.	.	.	„ „	„ 160
Dentalium	.	.	.	.	.	.	„ „	„ 163
Fasciolaria	.	.	.	.	.	.	„ 21E ¹	„ 32
Solarium	.	.	.	.	.	.	„ 24 ¹	„ 63

¹ Locality 11 is north and north-west of Maravatúr.
„ A west of Arialúr.
„ 21E north-east and west of Odium.
„ 24, reef in stream half a mile below Veraghúr.

Among the *Pelecypoda* the following forms appear to be new, *i. e.*, unfigured, by Dr. Stoliczka :—

Ostrea, sp.	.	.	.	.	.	.	Locy. 11	No. 14
Pholodomya ?	.	.	.	.	.	.	„ A.	„ 10
Panopæa, sp.	.	.	.	.	.	.	„ „	„ 13
Tellina, „	.	.	.	.	.	.	„ „	„ 27
Trigonia, „	.	.	.	.	.	.	„ „	„ 46
Avicula, „	.	.	.	.	.	.	„ „	„ 61
Ditto, „	.	.	.	.	.	.	„ „	„ 62
Mya, „	.	.	.	.	.	.	„ 21 ¹	„ 47
Exogyra, „	.	.	.	.	.	.	„ 27 ¹	„ 73

¹ Locality 21 is north-west and north of Odium.
„ 27 is east of Karapády.

A singular plicated tube of doubtful molluscan or annelidan origin is specimen No. 24, from the coral reef limestone near Naicolum (Loc. No. 2).

Echinodermata.—The small echinoderm No. 5, from the “Sponge bed” south of Naicolum (Loc. 3), appears to be new, as does also the encrinoid joint No. 4. The same may be said of an encrinoid joint found in the Utatúr clays (O. No. 64).

Bryozoa.—Two very beautiful small Bryozoa, Nos. 129 and 130, were obtained by me from the “Sponge bed” (Loc. No. 3). They are quite different from anything figured in the *Palæontologia Indica*.

Corals.—Considerable numbers of a very delicate little cup coral (*C. E.* Nos. 1—65) were found in white clays half a mile east of the Cudicád-Cullpády road, and rather nearer to the latter place. They appeared confined to a very small area, and were not met with elsewhere.

Plants.—Plant-remains, fossil-wood excepted, are very rare in the Trichinopoly cretaceous beds, but a few obscure specimens were obtained, *e. g.*—

An impression of a longitudinally ribbed stalk found at Seraganúr (S. No. 15).

A minute piece of a cycadeous (?) leaf in an indurated clay nodule from the Utatúr beds north of Cudicád (C. No. 3).

Minute fragments, apparently of cycadeous leaves, are traceable in some parts of small clayey nodules from the Utatúr beds (Nos. 67—720).

Locality No. 2.—The collection of fossils obtained from this patch of coral reef limestone is a very important addition to the fauna of this rather obscure formation, which yielded but little, if I mistake not, to earlier searches. My success in procuring specimens was due to the limestone having been quarried to some extent quite recently. All the specimens found I obtained from the quarry chips, with only one or two exceptions.

Locality No. 3.—This locality, which does not appear to have been known to Mr. Blanford as a rich hunting ground, shows three sets of fossiliferous beds, the lowest being coarse calcareous gritty beds with a few fossils and many washed-up pebbles of the coral reef limestone, also some masses almost deserving the name of boulders of the same rock. On these rests the "Sponge bed," an argillo-calcareous sandstone. On this again lies a clay bed with large indurated nodules, containing occasional Ammonites and Nautili with a few other shells. These are easily distinguishable by their light color, pale yellow or buff, while the "Sponge bed" fossils and those from the lower beds are mostly of a distinctly brown color.

The fossils from the "Sponge bed" were nearly all found within a very small space of ground, on the very basset edge of the beds, or the upper two or three feet of the gritty talus. The fossils met with, beside the sponges, rhyncholites, echinoderms and encrinoid joints already mentioned, were *Cidaris* spines, *Belemnites*, small Corals, Bryozoa, *Serpulæ* in great variety and numbers, large numbers of *Tubulosteuum callosum*, numerous *Gryphæa* and Oysters, and lastly, a number of small shells; both *Gasteropoda* and *Pelecypoda*, not forgetting a few small Ammonites. I do not recollect any other fossil locality in which I obtained so rich a collection, in an equally small space, reckoning the richness by the number of species.

Locality "O."—Mr. Blanford, in his Memoir on the cretaceous rocks, speaks of the small clay nodules near Utatúr as hardly ever containing any fossils. This statement is, I think, rather too strong, and calculated to deter future collectors from searching one source of valuable fossils. My own experience is, that they are not common in the small nodules, but still common enough to encourage search. I got several (eleven I think) in a morning's general search, without devoting more than half an hour specially to breaking nodules. Two of the eleven are certainly valuable specimens, the rhyncholite-like bodies referred to above (Nos. 26 and 27).

NOTES ON THE GENUS *SPHENOPHYLLUM* AND OTHER *EQUISETACEÆ* WITH REFERENCE TO THE INDIAN FORM *TRIZYGIA SPECIOSA*, Royle (*Sphenophyllum trizygia*, Ung.), by OTTOKAR FEISTMANTEL, M.D., *Palaontologist, Geological Survey of India*.

Last year a peculiar discovery was announced by Mr. Stur, at Vienna, on the relations of certain genera of Equisetaceous plants in the coal-formation. The observations refer also to the genus *Sphenophyllum*; so it will not be out of place to note this discovery, and to add some remarks on those plants with reference to the Equisetaceous plants in the Indian coal-beds, especially to *Trizygia speciosa*. The most common genera of the *Equisetaceæ* in the carboniferous formation are those which were described as *Calamites* (Suckow, 1784), *Asterophyllites* (Brongniart, 1828), *Annularia* (Sternberg, 1822), and *Sphenophyllum* (Brongniart, 1828). These were all described as distinct genera.

In 1852, however, Professor Ritter von Ettingshausen,¹ placed the genus *Asterophyllites*, as "*rami et ramuli*," to *Calamites*, although, as it appears, there was no direct evidence for the proceeding. In 1869 Mr. W. Carruthers² united all the three genera, i.e., *Asterophyllites*, *Annularia*, and *Sphenophyllum* to one group under the name *Calamites*, considering them as three different forms of foliage of this one genus, although, as it appears, the author had no direct evidence for this theory.

Professor Schimper (1869) placed the genus *Asterophyllites*, which he named *Calamocladus* under the heading "*rami et ramuli foliosi*," to *Calamites*; but *Sphenophyllum* and *Annularia* remained independent genera.

Professor Weiss (1871) again³ urges the independent nature of all the genera abovenamed; and so does Professor Heer, even in his recent publications.

In 1874 it was shown by Professor Williamson,⁴ who based his conclusion on the microscopical structure, that *Asterophyllites* and *Sphenophyllum* were very closely related genera.

In 1876 another systematical place was assigned to *Sphenophyllum* by Professor Schenk,⁵ who arrived at the conclusion that *Sphenophyllum* is more related to the *Lycopodiaceæ* than to the *Equisetaceæ*.

To this Mr. Stur wrote a reply under the title "*Ist das Sphenophyllum in der That eine Lycopodiaceæ,*"⁶ where he endeavoured to show that the systematical position of *Sphenophyllum* is with the *Equisetaceæ*.

So stood the case till last year, when Mr. Stur announced his discovery,⁷ which was as follows: On a slab of shale were found several branches of an *Asterophyllites* with branchlets, which showed the foliage of a *Sphenophyllum* (*Sph. dichotomum*), and had a fructification of the kind of *Volkmania*, (Stur). On other

¹ Steinkohlenflora von Radnitz, Abh. d. k. k. geol. Reichsanstalt, Vol. II, p. 24.

² In Seeman's Journal of Botany, 1867.

³ Fossile Fl. d. jüngst. Steinkohlfl. und des Rothliegenden, &c., pp. 107, 108, 2nd Part.

⁴ Philosoph. Trans. R. Soc., Vol. 164, p. 41 et seq., 1875.

⁵ N. J. f. M., 1877, p. 435, Refer.

⁶ Jahrb. d. k. k. geol. Reichst., 1877, Vol. XXVII, pp. 7—32.

⁷ Verhandl. d. k. k. geol. Reichsanstalt, 1870, p. 327. See N. Jahrb. f. Min., &c., 1879, pp. 256 and 260.

specimens the same *Asterophyllites* is said to have a fructification of the kind of *Bruckmannia* (Stur), and to be preserved in such a manner, that it has to be considered as branches of *Calamites*, preserved on the same slab of shale.

The conclusions to which Mr. Stur arrived are that *Sphenophyllum* is no peculiar genus, but belongs to *Asterophyllites*, and both *Asterophyllites* and *Sphenophyllum* are branches of *Calamites*.

Professor Williamson and Professor E. Weiss have published their opinions about this remarkable discovery.¹

Professor Williamson considers the connection of a *Sphenophyllum* and *Asterophyllites* as quite probable, and finds in it the confirmation of his own views on the relation of *Asterophyllites* and *Sphenophyllum*; but he thinks it impossible that both these genera should be the branches of a *Calamites* of the ordinary type, as it occurs in England, the structure of *Asterophyllites* and *Sphenophyllum* being totally different from that of *Calamites*.

Professor Weiss concurs with Professor Williamson as regards the impossibility of *Asterophyllites* and *Sphenophyllum* belonging to *Calamites*; but he is not prepared to accept the view that all *Asterophyllites* and *Sphenophyllum* should be closely related, and he finds a distinguishing character in the fructification. He says (l. c.), p. 264:—

“From the admission that branches with the appearance of *Asterophyllites* and *Sphenophyllum* may be found on the same plant, as observed by Stur, it would not at all follow that *Asterophyllites* in general is identical with *Sphenophyllum*, and still less that both these should be identical with *Calamites*.”

Professor Weiss therefore seems to allow that *Asterophyllites*-like branches may be found with *Sphenophyllum*-like branches on the same plant, there being also two other genera, i.e., *Cingularia* and *Bowmanites*, which have *Asterophyllites*-like stalks. *Sphenophyllum* and *Asterophyllites* of the carboniferous formation also agree in the arrangement of the leaves, all being arranged in whorls. But still he maintains the independence of *Sphenophyllum* in other cases.

If we now turn to the Equisetaceous plants in the Indian coal-beds, we find especially three forms—

Phyllothea (not very frequent, and in the Raniganj group only).

Schizoneura (rare in the Barakar group, but very numerous in the Raniganj group).

Trizygia (in both the Barakar and Raniganj groups).

Besides these many other stalks, without certain affinities.

The genus *Phyllothea* is known from the lower (palæozoic) coal-beds, the Newcastle beds and Wianamatta beds in New South Wales, and from the upper mesozoic beds (Bellarine-beds) in Victoria; from jurassic-beds in Siberia (Altai, Lower Tunguska river² and Eastern Siberia), and in Italy.

¹ N. Jahrb. f. Min., 1879, pp. 256 and 260.

² The formation with fossil plants in these two districts is jurassic, according to the last communication of Prof. Schmalhausen (Bull. d. l'Acad. des Sc. d. St. Petersburg, Vol. XI, pp. 77-81), containing *Phyllothea*, *Sphenopt. anthriscifolia*, *Asplenium whitbiense*, var. *tenue*, *Zamites inflexus*, *Podozamites eichwaldi*, *Ctenophyllum*, *Rhiptoxamites* (Nöggerathia), *Czekanowskia rigida*, &c.

There is no representative of this fossil plant in the carboniferous beds of Europe, the leaves being joined to an undivided spathe at their base, and free in the upper part.

As regards the other two, *Schizoneura* and *Trizygia*, I find the following remark about them in Grand'Eury's great work on the carboniferous flora in France,¹ page 404:—

“Il faut cependant bien reconnaître que certaines plantes des terrains secondaires inférieurs ont des attaches avec celles des terrains primaires ... le *Trizygia speciosa* de Royle, ressemble à un *Sphenophyllum oblongifolium* qui deviendrait beaucoup plus ample ; les *Schizoneura* du grès bigarré y suppléeraient aux *Asterophyllites*.”

As far as *Schizoneura* is concerned, this thesis seems probable, this genus also having linear leaves, in whorls, which are however in most of the cases joined to two broader, encircling leaves, which morphologically originated from a spathe (sheath), to which all the leaves are joined in the beginning of the growth of the plant.

With *Trizygia* we will have to admit a slight modification. *Trizygia* was first proposed by Royle on account of the arrangement of the leaves, always six in three pairs on one side of the joints ; this character is completely constant in all the specimens hitherto observed ; the species was *Triz. speciosa*.

McClelland (1850) described it as *Sphenophyllum speciosum* ; Unger (1850) as *Sphenophyllum trizygia*.

I myself followed Unger's example in my first notices on the Damuda flora (1876) ; but after these various researches on the nature of the carboniferous *Equisetaceæ*, I would return to Royle's original denomination, i. e., *Trizygia*.

From the preceding notes on the genus *Asterophyllites* and *Sphenophyllum*, it would appear that some forms of these two genera may belong to the same plant, but in some other cases *Sphenophyllum* is an independent genus.

In the Indian coal-fields the form *Trizygia*, said to be representative of the carboniferous *Sphenophyllum*, is not associated with any *Asterophyllites*, there being no true *Asterophyllites* found ; nor can it belong to *Schizoneura*, which to some extent can be considered as representing the *Asterophyllites* ; for amongst the very numerous specimens of *Schizoneura* from the Indian coal-beds, not one specimen was observed which would show that the *Trizygia* might in some way be connected with *Schizoneura* ; in the Talchir coal-field there is *Trizygia* without *Schizoneura*, and in the European Trias, where *Schizoneura* occurs, no trace of any form of the kind of *Trizygia*, or any *Sphenophyllum*, has hitherto been detected. *Trizygia* can therefore very well be considered an independent genus, having no connection with *Schizoneura*, as those forms of *Sphenophyllum* which have no connection with *Asterophyllites* ; but I also think *Trizygia* will have to be considered as differing from the true *Sphenophyllum*.

In this latter the leaves are arranged in complete whorls round the joints, and the stalk is pretty thick, so that we have to consider it as an erect plant, growing

¹ Flore carbonifère du Dptmt. de la Loire et du Centre de la France, 1877.

above the surface of water, like *Asterophyllites*. In the Indian plant, however, the leaf whorls are incomplete, there being always only six leaves, on one side of the joint, arranged in three pairs; the stalks are thin in comparison with the size of the leaves, showing perhaps that the *Trizygia* was a plant which floated on the surface of water.

In my paper on some fossil plants from Raniganj,¹ although placing the Indian form with *Sphenophyllum*, I pointed out all these differences, and distinguished two groups of *Sphenophyllum*.

At present I would formulate my view in the following manner:—

EQUISETACEÆ.

CALAMARIÆ.

Group: *Sphenophylloideæ*.

a.—Leaf whorls complete round the joint; number of leaves variable; leaves of the same size and shape in the same whorl.

The true carboniferous *Sphenophyllum*.

b.—Whorls incomplete on one side of the joints; number of leaves six, arranged in three pairs, of which each differs from the other in size and partly also in shape of the leaves.

The *Trizygia* of the Indian coal-beds.

In this sense *Trizygia* may be considered as representative of the carboniferous *Sphenophyllum*, but is an independent genus.

We have therefore—

Phyllothea, representing in the fossil flora the living *Equisetum*.

Schizoneura, representing perhaps the genus *Asterophyllites* of the palæozoic formation.

Trizygia, representing the genus *Sphenophyllum*, although differing from it.

ON MYSORIN AND ATACAMITE FROM THE NELLORE DISTRICT, by F. R. MALLET,
F. G. S., *Geological Survey of India*.

Mysorin.—The occurrence of copper in the District of Nellore, as well as in other adjacent parts of the country, appears to have been first brought to the notice of Government by Dr. Benjamin Heyne in the early part of the present century. In his "Tracts on India," published in 1814, an account is given of the rocks in the metalliferous region, and some details as to the nature of the ore. But the working of the mines, which appears to have been carried on extensively at an earlier period, was in abeyance at the time of Dr. Heyne's explorations, so that he was unable to obtain any reliable information as to the mode of occurrence of the ore, or its quantity. He was led, however, to suppose that the amount

¹ Jour. As. Soc., Bengal, 1876, p. 342.

was very considerable, and that the working of the mines "had not been given up for want of ore, but from the jealousy of the Rajahs, who wished to hide such a treasure as long as possible from their superiors." Specimens of copper ore were obtained by Dr. Heyne, from near the surface, in several localities. Most of it was "malachite and mountain green," but there was also a dark-colored ore, intimately associated with the above, a sample of which was sent to London, and analysed by Dr. Thomas Thomson. His results were published in the *Philosophical Transactions* for 1814, and were reprinted as an appendix to Dr. Heyne's work above referred to. Dr. Thomson described the ore as follows:—

"All the specimens of this ore which I have seen are amorphous; so that, as far as is known at present, it never occurs crystallized. Quartz crystals indeed are imbedded in it abundantly and very irregularly. Sometimes they are single, sometimes they constitute the lining of small cavities to be found in it. These crystals are all translucent. In some rare cases they are colorless; but by far the greater number of them are tinged of a yellowish-red, and some few of them are green. The mineral is likewise interspersed with small specks of malachite; and with dark, brownish-red, soft particles, which I found to consist of red oxide of iron.

"The color varies in consequence of the irregular distribution of these extraneous substances. One specimen, which was the most free from the malachite and the red particles, was of a dark blackish-brown color. But in general the color is a mixture of green, red, and brown; sometimes one and sometimes another prevailing. Small green veins of malachite likewise traverse it in different directions.

"The fracture is small conchoidal, and in some parts of the mineral there is a tendency to a foliated fracture. The lustre is glimmering, owing, I conceive, to the minute quartz crystals scattered through it. The kind of lustre is resinous; and on that account and the varieties of colors, this ore has a good deal of the aspect of serpentine.

"It is soft, being easily scratched by the knife.¹ It is sectile. The streak reddish-brown. The specific gravity 2·620.

"It effervesces in acids and dissolves, letting fall a red powder. The solution is green or blue, according to the acid, indicating that it consists chiefly of copper."

The result of Dr. Thomson's analysis was as follows:—

Carbonic acid	.	.	.	.	.	.	.	16·70
Peroxide of copper	.	.	.	.	.	.	.	60·75
Peroxide of iron	.	.	.	.	.	.	.	19·50
Silica	.	.	.	.	.	.	.	2·10
Loss	.	.	.	.	.	.	.	·95
								<hr/>
								100·00

The oxide of iron and silica he regarded as mechanically mixed, and he therefore considered the ore to be an anhydrous carbonate of copper, and a new

¹ The hardness is given as 4·25 in Dr. Thomson's *Mineralogy* of 1836.

mineral species. It is described (in an abridged form from the abovementioned paper) in his *Outlines of Mineralogy* (7th edition, 1836) as anhydrous dicarbonate of copper. In most works on mineralogy, of a date subsequent to Dr. Thomson's, the ore is alluded to as a doubtful species under the name of *mysorin*.¹

With reference to the locality in which the *mysorin* was found, Dr. Heyne wrote: "Malachite and mountain green probably constitute the great mass of the ore in the copper veins, but an immense nest of the anhydrous carbonate of copper was found at Ganypittah, a village belonging to a Jaghierdor in the Venkatygherry district, about 40 miles west of Ongole. It exists there in a rock of the nature of gneiss, but considerably disintegrated, and the quantity of it must be immense, as forty coolies' loads were procured by a little digging, and sent to Mr. Travers, the Collector of the district, and almost as much remained which had been dug out, but which was not carried away."²

The village of Ganypittah—spelt Guramanypenta by Dr. Heyne in a pamphlet subsequently published by him, Gurumanipenta by Lieutenant Newbold, and Gunnypentah on the Atlas sheet—is 48 miles south-west of Ongole. From the bearings of the village from Nellore and Cuddapah given by Dr. Heyne, as well as from allusions to other villages in the vicinity, it is perfectly clear that *west* was a mere slip of the pen on his part.³

Amongst the specimens which were forwarded to the Geological Museum in 1873, for incorporation in the series illustrating the mineral resources of India, which was sent to the Vienna exhibition, was a parcel of perhaps a hundredweight, or more, of copper ore from "Gudisa Gundla near Ganmanipenta and Yerripali, Nellore District." Yerripali is a village about four miles from Ganmanipenta. A portion of the ore was reserved for the Geological Museum,

¹ From Mysore. The country, however, in which it was found, lies considerably to the east of the Mysore territory of the present day.

² In the fourth volume of the *Journal of the Asiatic Society of Bengal* (1835), there is a paper by Mr. James Prinsep, giving the results of his analyses of three samples of copper ore from the Nellore District. The analysis of one of these, which Mr. Prinsep thought might be the same ore as that examined by Dr. Thomson, is as follows:—

Hydrated carbonate of copper	...	...	...	...	68.5
Sulphuret of copper	...	...	...	...	0.2
Sulphuret of iron	...	...	...	...	12.4
Oxide of iron, silice, &c.	...	...	...	...	25.1
					106.0

It is, however, alluded to by Mr. Prinsep himself as an imperfect analysis. The third ore examined was sulphide of copper (63.0 per cent.) mixed with hydrated carbonate (31.7 per cent.) and some oxide of iron and silice. In the same paper there is an extract from a pamphlet, published by Dr. Heyne subsequent to the issue of his 'Tracts on India,' in which he describes the appearance of an ore which he considered to be of the same kind as that previously forwarded to Dr. Thomson, but as it seems clear that Mr. Prinsep was right in believing that Dr. Heyne had mistaken the sulphide with carbonate for the *mysorin*, it is unnecessary to quote the description.

The copper-bearing localities of Nellore and the neighbouring country have been further described by Lieutenant Newbold in volume VII of the *Journal of the Royal Asiatic Society*.

³ *Journ. As. Soc. Bengal*, Vol. IV, p. 575.

and while arranging the copper ores in the economic collection some time ago, I was struck with the outward resemblance of part of the Nellore ore to the Mysorin as described by Dr. Thomson. It is, however, only recently that I have had the opportunity of making a complete examination of it.

The ore, as sent, occurs in irregular broken pieces of various sizes up to about three inches diameter. It is a most heterogeneous mixture, made up of over half a dozen different minerals, some of which are, however, much more abundant than others. Taken roughly in the order of their relative abundance, there are visible to the naked eye, or with a lens:—

The dark reddish-brown ore in question.
 Malachite.
 Chrysocolla.
 Quartz.
 Yellowish-brown ochre.
 Chalcocite.
 Calcite.
 Bornite.¹

Pieces of pure malachite are not to be found, the mineral being greatly mixed up with chrysocolla and other minerals. Some portions of it, owing to disseminated reddish-brown specks, and specks of chalcocite, have a dark tinge. The chrysocolla, which is green and greenish-blue in colour, occurs both mixed with the malachite, &c., and in the form of thin seams, and as the linings of small cavities. The quartz is crystalline and generally colorless or nearly so, but it appears to have a green or yellowish colour from being imbedded in malachite or chrysocolla or ochre, or from having such running through it in thin seams. The proportion of chalcocite is quite small, but occasionally a tolerably pure mass an eighth of an inch long, or more, may be observed, and it can be seen scattered through many pieces of the ore with the aid of a lens. Calcite is a rare mineral only observed on a few specimens in the form of very thin seams. Bornite is extremely uncommon: only a very few specks have been detected. Some pieces of the ore consist mainly of malachite and chrysocolla, others mainly of the dark-coloured ore.

The most homogeneous portions of the latter have to the naked eye a dark reddish-brown colour, but viewed with a lens they are seen to be finely mottled in dark brownish-red and green. A thin section, which to the naked eye has a reddish-brown colour by reflected light, when viewed with a lens by transmitted light, shows this mottled structure still more plainly. The relative proportion of the two colours varies greatly. Occasionally a patch is found in which the green is almost absent. It is but rarely that one finds a surface of a quarter of an inch square that is not intersected by thin green seams of malachite and chrysocolla, which traverse the ore in different directions. Specks of chalcocite are also visible, and, very occasionally, those of bornite. The ore contains a few small cavities, partially filled with red ochreous oxide of iron.

¹ Besides these there are visible in a few specimens, which include some of the gangue-stone, hornblende, garnet, mica, &c., the matrix of the ore being, according to Lieutenant Newbold, mica and hornblende-schist.

The lustre may be described as dull to the naked eye, but glimmering under the lens. Fracture imperfect conchoidal. On scratching the ore with a knife the streak is seen to vary in colour owing to the mottled character of the substance. Generally it is greenish and brownish-yellow. In the patches which are free from green it is brownish-red. The fragments which I selected for analysis yielded a buffish-gray powder. Hardness of the ore about 4.0. Specific gravity 3.80. It effervesces with cold dilute acid, yielding a green or blue solution and leaving a red powder undissolved. On heating this powder with strong hydrochloric acid, ferric oxide is dissolved, and a white powder remains.

On comparing the description Dr. Thomson has recorded of the ore analysed by him with that just given of the ore I have examined, and recollecting that Dr. Heyne has stated that the mysorin occurs in an immense nest at Gannypentah, and that the ore examined by me was sent as the ordinary ore of the same locality, I do not think there is much room for doubt as to Dr. Thomson's ore and mine being the same. The only discrepancy of importance so far is in the specific gravity. Dr. Thomson found it to be 2.62, I 3.80. It may be observed on this point that it seems remarkable that while malachite has a specific gravity of 3.7—4.0, the corresponding anhydrous carbonate should have as low a specific gravity as 2.62. The low specific gravity can scarcely be ascribed to impurity, as Dr. Thomson's analysis shows this to consist almost entirely of ferric oxide.

In the crucial point however—the presence or absence of water—my analysis differs fundamentally from Dr. Thomson's. The fragments selected for analysis showed under the lens the brownish-red and green mottling alluded to above. Minute veins of malachite and chrysocolla were also visible, as well as specks of chalcocite, it being found impossible to obtain a sufficiency of the substance free from such admixture. Minute quantities of barite and probably calcite were also present, although they were not detected by the eye. The result of my analysis of the ore (dried at 100° C.) was as follows:—

Copper equiv. to .56 of S.	2.22
Copper calculated as cupric oxide	61.46
Ferric oxide (with tr. of Al_2O_3)	6.74
Lime	.26
Baryta	.55
Carbonic acid	15.18
Silicic acid	4.39
Phosphoric acid	tr.
Sulphuric acid	.29
Sulphur	.56
Water ¹	9.02
	<hr/> 100.67 <hr/>

The barium sulphate was included in the residue insoluble in aqua regia,² together with the bulk of the silica, which was entirely soluble in alkali. The sulphur was clearly derived from the chalcocite. The ferric oxide was evidently

¹ The amount of water was determined by direct weighment.

² Also in the residue insoluble in hydrochloric acid.

mechanically mixed, being left (with silica, &c.) as a red powder when the mineral was treated with dilute acid.

It was not found possible to isolate sufficient chrysocolla in a pure state from the ore to make a separate analysis of it. Adopting, however, the normal composition of the mineral, the above figures would be equivalent to—

		Cu.	CuO.	Fe ₂ O ₃	CaO.	BaO.	CO ₂	SiO ₂	SO ₃	S.	H ₂ O.
Malachite	... 77.02	...	55.65	...	...	...	14.98	...	...	...	6.39
Calcite	.. .46	...	...	...	.26	...	.20	...	...	...	...
Chrysocolla	... 12.83	...	5.81	...	...	...	...	4.39	...	...	2.63
Barite	... .84	...	...	...	...	.55	...	...	.29	...	...
Chalcocite	... 2.78	2.22	...	...	...	...	...	...	...	.56	...
Ferric oxide	... 6.74	...	...	6.74	...	...	...	...	...	...	...
	100.67	2.22	61.46	6.74	.26	.55	15.18	4.39	.29	.56	9.02

After deducting the cupric oxide and water equivalent to the silica, and the carbonic acid equivalent to the lime, there remains a residue of, water 6.39, carbonic acid 14.98, cupric oxide 55.65; quantities which have the oxygen ratio of 1: 1.92: 1.97; the oxygen ratio in typical malachite being 1: 2: 2. It is clear, therefore, that the ore is an impure malachite owing its dark colour to admixture with ferric oxide and chalcocite. Some specimens, indeed, of the Gannypentah ore, which are seen to be impure malachite by the eye, have a dark colour owing to a smaller admixture of the same kind.

It is not certain that the lime exists as calcite, but it is probable, calcite having, as before remarked, been found in some specimens of the ore. The point is, however, of no importance with reference to the main question. Thus, if the lime be included with the chrysocolla, the above-mentioned ratio will be 1: 1.94: 1.99.

I have alluded to small portions of the mysorin in which, when viewed with a lens, green is almost absent. Fragments of such, when dropped into dilute acid, give merely a minute bubble or two of carbonic acid; the liquid is faintly tinged with green, and the fragment remains almost unacted on. When heated with strong hydrochloric acid, iron is abundantly dissolved. Such portions of the ore are in fact merely ochreous ferric oxide. The amount of effervescence increases with the amount of green visible in the specimens experimented on.

Atacamite.—Amongst the specimens of copper ore from the Nellore district in the Museum, there is a mass of chalcocite, which appears to have been originally obtained by Mr. Kerr, a gentleman who endeavoured, but unsuccessfully, to work the mines about the year 1835. The specimen weighs about six pounds, and evidently formed a portion of an irregular vein, two or three inches thick. It contains a few disseminated crystals of magnetite, and is intersected by small,

irregular seams containing (with some malachite) dark emerald green, translucent, crystals, which, on examination, proved to be atacamite. The point is worth notice, in that the locality in question is, I believe, the only one in which atacamite is known to occur in India.

ON CORUNDUM FROM THE KHÁSI HILLS, BY F. R. MALLET, F. G. S.,
Geological Survey of India.

Amongst the specimens lately transferred from the Economic to the Geological Museum, was one of "hone stone", locally known as "maushynrut", from the Khási Hills. Its high specific gravity attracted my attention, and on examination it proved to be corundum. It is a finely granular, light gray, or grayish-white rock, containing microscopically minute specks of a translucent, dark red, mineral. It scratches topaz with ease. The specific gravity is 3.93. It appears from information obtained by Colonel Sherer, Deputy Commissioner of the Khási and Jaintia Hills, to whom the matter was referred, that the mineral is procured at a village called Nongrynew "towards the north-west of, and at a distance of about two days' journey from Nongstoin." Nongstoin is the capital of a petty Khási state; latitude $25^{\circ} 31'$ longitude $91^{\circ} 20'$. It would seem that there are no quarries of the stone, but that the villagers pick up pieces found loose on the surface, and use it locally, as before mentioned, for hone or rather grind-stones.

As the edge of the hills to the north-west of Nongstoin is about 30 miles from that place, and within 15 miles of the Brahmaputra, it would appear that the locality where the corundum is found cannot be very far from the edge of the hills, and that it is within a day or two's journey from the river, for carts or laden animals. If, therefore, the stone occurs in large quantity—a point respecting which no information is available—it is worth attention commercially. Corundum is found in large quantity in South Rewah,¹ and notwithstanding the fact that it is more than a hundred miles from the railway, over a road of which the first third is execrable even for laden cattle, and impassable for carts, the corundum is exported to some extent to Mirzapur. The Khási stone, therefore, if found near the edge of the plains, would be far more advantageously situated with respect to carriage. The Rewah corundum is a tougher, less easily pulverized stone than the Khási. Whether the powder of the latter, however, would do the same amount of work as that of the Rewah, is open, perhaps, to question. We are indebted to Colonel Sherer for a specimen of the corundum lately received, weighing about 20 pounds and measuring about $4 \times 7 \times 9$ inches. It had evidently been in use as a grindstone.

¹ Records, Vol. V, 20, Vol. VI, 43.

NOTE ON THE JOGA NEIGHBOURHOOD AND OLD MINES ON THE NERBUDDA, by
G. J. NICHOLLS, C. S., *Officiating Commissioner of Excise, Central Provinces.*

In the tract of country between the Great Indian Peninsula Railway, the Chota Táwa (which divides the Nimár and Hoshangabád districts), the Nerbudda and the Ganjál river, most of the western area is composed of metamorphics and Bijáwars, and these in the eastern area pass under alluvium.

Granitic and syenitic rocks show at Harda in the river bed. These rapidly pass into gneiss as we go north-west towards Handia. The gneiss soon passes under cherty bands and quartzose breccia. Due north from Harda about seven miles, and to the east of the road to Handia, the streams lay open beds of much disintegrated granitoid or gneissic rock which would probably yield kaolin.

Between two and three miles south of Handia small hills, with a westerly run, are met, composed of a peculiar quartzite belonging to the Bijáwar series.

At Handia the bed of the Nerbudda is of granite, the felspar being of a marked red colour. Across the river at Nimáwar, the quartzites again come in.

From Harda to the south-west, granites are found till the Máchak valley is met near Mandla. Further down the railway line trap comes in, a softish red or reddish purple stone, easily cut and used for bridge work.

Down the Máchak which runs in a north-west direction at Dhanwára, a coarsely crystallized protogene rock forms the bed of the stream.

At Deopur a limestone has been quarried to a considerable extent.¹

Westward of this, through Gambir to the Chota Táwa, there is much schist and gneiss, with trap outliers superimposed. Going due west of Harda to Sontalai, I quickly left the granite and syenite and passed beyond the gneiss. From this to Sontalai, bands of yellowish brown chert and outcrops of a highly silicious limestone (Bijáwar) alternate in a most confused manner. Where there are hills, as at Niljhar, they are mostly of quartzite with chert and jasper. The surface of the limestone is much weathered and gnarled, and the silicious layers stand out in relief, often assuming the half vitrified look of hornstone. Close to Sontalai, there is much ferruginous debris, probably from the numerous iron melting furnaces once worked on the western side of the village.

A curious conglomerate rather than breccia occurs in the stream west of the village. In the afternoon I went to the iron mine about two and a half miles from Sontalai near the Máchak river, seemingly a pocket of hæmatite and iron ochre it has been worked out to a depth which is below the present level of the water in the pit. About here, frequent and quick transitions take place from gneiss to schist and narrow greenstone or diorite bands, giving the appearance of interstratification. The position of these and of the schists is generally nearly vertical. Lumps of quartz and nodules of trap lie about on the ground, also a few agates and flints. From Sontalai to Joga across the Anjan, the trap and greenstone dykes, and metamorphic schists disappear. The elevations are almost entirely of quartzite, and the yellow-brown cherty jasper is much stronger. South of

The specimens forwarded are of Lameta limestone, the same as that quarried at Jabalpur.

H. B. M.

Joga Khurd, a strong course of Bijáwar grey weathered limestone strikes to cross the Nerbudda, which river here runs from north to south. The limestone course can be seen forming a reef across the bed of the Nerbudda, but not quite at right angles. The course is nearly north-east-by-east to south-west-by-west.

Between Joga Khurd and Joga Kalán, cherty or jasper breccia is very common, and almost seems to overlie the Bijáwar limestone. From Joga Khurd it is about half a mile to the excavations known all through the country as the "Chándi Khadán" (silver mine).¹

The pits are in two parallel lines. The most northern line is apparently a continuous excavation of about half a mile in length on the Bijáwar limestone band. The depth and width vary greatly, and the direction runs pretty straight. These open excavations end about 250 yards from the banks of the Nerbudda; the line, I think, generally showed some elevation as compared with the ground on either side. The depth may be generally about 25 feet, and the breadth 15 feet. About 250 yards south of this line of excavation is the second line of excavations; these are generally much narrower and much deeper, much more like evidences of sinking on a lode. Here generally there was a determined dip of about 80° to the north, the strike being as described where the limestone reefs cross the Nerbudda. Where the limestone ridge comes to the surface, the weathered appearance of the rock is remarkably wild and weird. The excavations are not all in one line or continuous. Apparently parallel and intersecting lodes or leaders have been followed.

The length of these excavations was less than that of the northern run. In some places from ten to twelve feet in width appear to have been dug out, but generally six feet would be the average. In some parts a considerable depth, about 40 feet, was attained; only in one pit is water found. This has a depth of 8 feet in a small pit or pocket at the extremity of the excavation, which elsewhere was about 30 feet deep. From this I took most of my specimens.

Although at the surface the rock is very contorted, and shows some sign of concentric formation and numerous silicious bands like hornstone, we soon get down into fairly settled ground. But at the bottom I saw a tendency to pockets, there being round holes or nests picked out by the old miners. From the depth where I was working, I could see nothing else to lead me to think that the lode went no deeper; but I had not the opportunity of testing this. From the specimens procured it will be seen that the limestone, through which probably a strong lode ran, is interspersed with mineral. This shows most frequently in the

¹ The reputation of the old pits at Joga as silver mines is certainly of no very recent invention. In March 1855 my attention was drawn to them by Captain Nembhard, then Assistant Commissioner at Hoshangabad. I found the mines just as described by Mr. Nicholls (there were then no maps of the ground); the deposit seemed to be so thoroughly worked out that I had some difficulty, with only a hammer, to make out what the ore was. A very much richer ore than any now visible was no doubt found in the old excavations, and it is quite possible that similar bunches may still lie to the deep of the old workings. The Karpura iron ore, which is probably that referred to by Mr. Nicholls, occurs as a vein in the Bijáwar jasper-breccia. It is a rich red-hæmatite, though in places much mixed up with the jasper rock.

PART OF
HOSUNGABAD

(from Mr Hackett's Survey)

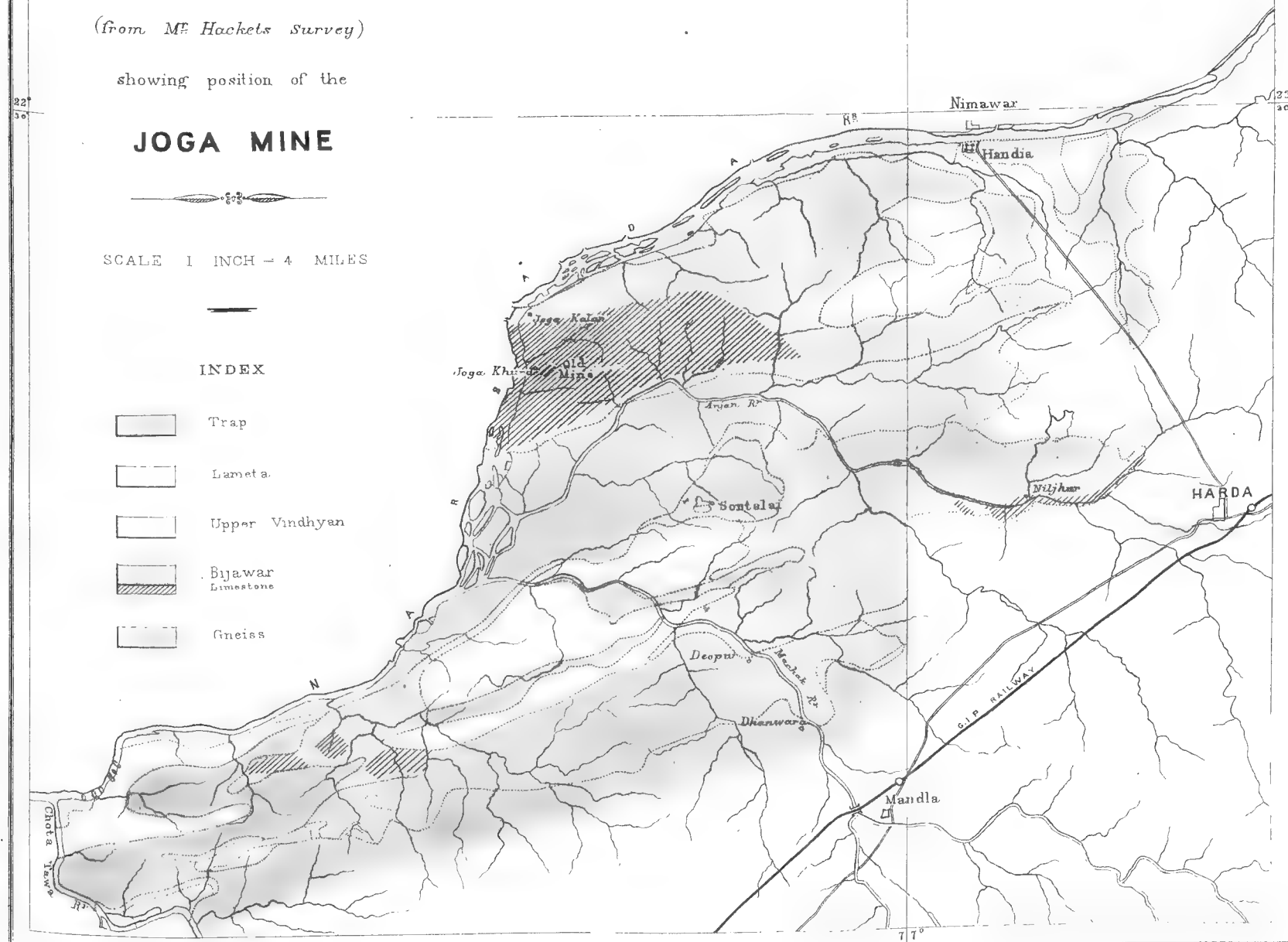
showing position of the

JOGA MINE

SCALE 1 INCH = 4 MILES

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lines of jointing. It would look as if occasionally I have got fragments of leaders or strings belonging to a large lode. I saw no marks of blasting, or of the use of crowbars.

The country around is all forest, and the soil very poor. The Mowassi Kurku is almost the only inhabitant. He is superstitious and would never have been able to execute the mining work to be seen at Joga. This was probably done by the Patháns, who held the fortress at Joga Kalán, a building supposed to be of the time of Alamgir. Many other reasons besides exhaustion may have led to the abandonment of these works: for instance, inability to control the water in the lower levels, want of acquaintance with machinery for raising the ore with tools, and methods of blasting for breaking down the rock, or the fall of the Mogul power at Handia, and the succession of the Mowassi and Pindhári robber hordes. One cobra put to flight five workmen of mine. They considered him to be the guardian of the treasures. In prospecting both this year and last, I had to use my rifle.

Possibly it might be worth while to spend a little money in trying to expose the lode or in driving cross-cuts. Water power is probably available for stamping.

NOTE.

The samples from the Joga mines, sent by Mr. Nicholls to the Geological Survey Office, were as follows:—

No. 1.—Dug by Mr. Nicholls from the remnant of the *gangul*, or pocket, near the bottom of the ‘water pit’—gray dolomitic limestone, containing a few cherty layers: galena is very sparsely disseminated through both limestone and chert, and in one or two specimens, specks of copper pyrites were observed.

No. 2.—Dug out from side of the excavation of the ‘cobra pit’—specimens similar to No. 1.

No. 3.—Casing of a pocket in the ‘water pit,’ dug out by Mr. Nicholls—ferruginous, mangiferous, dolomitic limestone with cherty bands; galena and copper pyrites disseminated as in No. 1.

No. 4.—From debris at surface of ‘panther pit,’—gray dolomitic limestone with specks of galena.

No. 5.—Casing from ‘water pit,’ dug out by Mr. Nicholls—ferruginous, mangiferous, dolomitic limestone.

No. 6.—From debris of ‘water pit’ and ‘hyæna pit’—same as No. 5. Some pieces are sufficiently ferruginous to be called spathic iron. Contains a few specks of galena.

Besides the above, a quantity, perhaps half a cwt., of stone was sent, taken from the debris of several workings. It was similar to the sample No. 1.

None of the above described samples showed any signs of the existence of a lode. The galena is very scantily disseminated through the limestone and chert themselves. The percentage of ore to gangue is extremely small, so much so that it was necessary to pulverize and wash several pounds of stone to obtain sufficient galena for an assay. The specimens sent are themselves useless as an ore, although of course indicating the possibility of galena occurring in larger quantity. As they were mostly taken from the mere debris of the mines, they cannot be regarded as fair samples of what the average ore formerly extracted was. To really test the value of the mines, it would be necessary to excavate sufficiently deep to penetrate beneath the old workings.

The lead extracted from the galena was found to contain 21 ounces of silver to the ton; a very fair proportion, but certainly not one which would entitle the mines to the name of ‘silver mines,’ rather than lead mines.

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COLONEL J. F. SHERER,
Deputy Commissioner.

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10 stone hatchets (neolithic) from Vellore.

9 ditto ditto Bánda.

J. COCKBURN, Esq.

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SEN CARLOS RIBEIRO.

June 30th, 1879.

RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 4.]

1879.

[November.

NOTE ON THE "ATTOCK SLATES" AND THEIR PROBABLE GEOLOGICAL POSITION, *by*
DR. W. WAAGEN.

In the Records of the Geological Survey of India, Vol. XII, pt. 2, there is a paper by Mr. Wynne, entitled "Further notes on the geology of the Upper Punjab," which bears a special interest on account of the general views on the geology of that country. As many of the points treated of in the paper are yet to be considered as open questions, it seems not advisable to pronounce any opinion on them until further materials have been collected, but it may not be useless to notice some points which might be of value towards the elucidation of the questions discussed by Mr. Wynne.

There is before all the age of the "Attock slates." Mr. Wynne is quite right when he considers the evidence upon which the opinion of their being of silurian age is founded very scanty indeed; and only the absence of any other clue towards the determination of the age of those slates could at the time justify the opinion expressed in our joint memoir on Mount Sirban, that the occurrence of lower silurian fossils in gravels in the Kabul river, which lay approximately in the strike of the "Attock slates," would make a silurian age probable also for the latter.

It is very much to be regretted that to the careful search of Mr. Wynne the slates have proved absolutely unfossiliferous up to the present. Yet this sterility in fossils seems not to prevail at all localities. Among the materials which have been most liberally sent to me by the Geological Society of London, there are about a dozen specimens of a *Spirifer*, which bear, however, only the label "Punjab." These specimens are preserved in a black slate, which, if the specimens came really from the Punjab,—and there is no reason why this should be doubted,—must have belonged to the Attock slates, as there is no other rock known to me in that part of India which would bear similar petrographical characters, and from which the specimens could have come.

Though these fossils are more or less deformed by oblique pressure, yet the species can without difficulty be determined. All the specimens belong to one and the same species, and cannot be distinguished from *Spirifer keilhavi*, Buch., (*Sp. Rajah*, Salt.). As this species is one of those most characteristic of the carboniferous formation in the Himalaya, and as thus the determination of the age of the rocks from which these fossils came considerably differs from the age hitherto attributed to the Attock slates, it is necessary to be doubly cautious in accepting the current opinion regarding these slates.

The rock in which the fossils are preserved is, as stated above, a black, not very hard slate, such as I have seen to occur at many places in the Attock slates; but there are also outside of the Punjab some localities where similar slates occur. I have myself seen similar slates from the Milam pass which seem also to belong to the carboniferous formation, and seem to be there inferior to white limestones, also full of carboniferous fossils, the latter, however, of a much more recent type. Similar slates have been described by Lydekker from Eishmakam in Kashmir, whilst at other places in the same territory the carboniferous formation is composed nearly entirely of thick limestones. The slates of Eishmakam have been compared by Lydekker to the "Kiol group" and the limestones to the "Great limestone" of the outer Himalaya. Thus it might be very possible that in the Himalaya the carboniferous formation should present two sub-divisions, one older slaty, and one younger calcareous sub-division. This, however, does not prevent that at many localities the whole formation might be made up of massive limestones.

If, therefore, the fossils under consideration did not come from the Punjab, they might have come from several parts of the Himalaya. There is, however, no reason to doubt their coming from the Punjab. There exists in the Punjab a great amount of rocks perfectly similar in appearance to the rock in which the specimens occur, and if these rocks up to the present have proved apparently unfossiliferous, this does not exclude the possibility that there exist localities where fossils do occur. That all these fossils belong only to one species already goes far to prove that the slates containing them are not very rich in fossils. How much it depends on circumstances whether one does meet with certain fossils is also exemplified by the fact that I as well as Mr. Wynne have been searching in vain in the Salt-range for determinable plant remains, and yet there are several beautifully preserved plant remains from the Salt-range in the Geological Society's collection.

Thus we may fairly accept the indications of the label attached to these specimens of *Spirifer keilhavi* as correct; and from this it would follow, that the Attock slates will have to be considered in future as belonging very likely to the carboniferous period.

If we accept this view, one of Mr. Wynne's remarks becomes of special importance; this is that the limestones of Gandgarh remind one more or less of the great limestone of the Jamu hills. This would fit entirely into the state of things observed elsewhere, and the discrepancy, at least in the carboniferous formation, between Kashmir, Jamu, and Hazara would no longer be so striking as is supposed by Mr. Wynne. These limestones are entirely absent in the

neighbourhood of Mount Sirban, and this absence possibly might account for the marked unconformity there between the Attock slates and the more recent formations.

But also for these latter the determination of the Attock slates as of carboniferous age would have a deciding influence, as then the geological horizon they occupy might approximately be fixed. In the little memoir on Mount Sirban, Mr. Wynne and I have distinguished a group of rocks as "Below the Trias," consisting chiefly of cherty dolomite, to which are subordinate red sandstones and quartzites. We have separated these rocks from the Trias for the simple reason that there existed no proof of any kind that they belonged to that formation, and as we then considered the Attock slates as of silurian age, the number of formations to which those strata "Below the Trias" could have been assigned, was so very large, that it seemed only prudent not to express any definite opinion as to their age. Now the case is quite different: these beds would rest unconformably on the carboniferous Attock slates, and be succeeded conformably by upper triassic or rhætic strata; thus it becomes very probable that the strata "Below the Trias" represent the Lower Trias, *viz.*, Muschelkalk and Buntsandstein formations.

In his more recent memoirs Mr. Wynne introduces the designation of "Infra-triassic group" for these strata, and most recently he considers this group as identical with his "Tanol series," which is extensively developed in the northern part of Hazara; but such a homotaxis can hardly be maintained. Wynne's "Infra-triassic group," or the group "Below the Trias" of our joint memoir on Mount Sirban, consists chiefly of cherty dolomites, and exhibits sandstones and quartzites in a subordinate manner only, whilst according to the sections published by Mr. Wynne, the Tanol series consists chiefly of slates, sandstones, and quartzites, to which the dolomitic limestones are subordinate.

Besides this the thickness of the group "Below the Trias" and that of the Tanols is so enormously different that a comparison between the two is barely possible.

The only formation to which the Tanol series seems to bear some resemblance is the silurian of the more central parts of the Himalaya (Milam pass, Niti pass), where the fossiliferous beds consist also of white sandstones.

The apparent superposition of these Tanol rocks over the carboniferous Attock slates can be no reason for the rejection of such a parallelisation. Before it is possible to accept Wynne's view that the Tanols are more recent than the Attock slates, and pass upwards into the gneiss which composes the central Himalayan chains, much stronger proofs, stratigraphical as well as palæontological, than those published in his memoir must be adduced; and until decisive materials are available, it will be much more prudent to consider the whole silurian Tanol series as overthrown and faulted against the Attock slates. Then the riddles of the geology of Hazara will easily be solved.

ON A MARGINAL BONE OF AN UNDESCRIBED TORTOISE, FROM THE UPPER SIWALIKS, NEAR NILA, IN THE POTWAR, PUNJAB, by W. THEOBALD, *Geological Survey of India*.

The bone which forms the subject of the present remarks, and of which a figure of the natural size is given, is remarkable for exhibiting a structural adaptation which exists in no living species, and, so far as I am aware, has not yet been described in any fossil. It will be necessary, therefore, to refer it to a new genus which I propose to associate with the name of the illustrious fellow-worker of Falconer, Colonel Cautley, and characterize as follows:—

CAUTLEYA.

Genus *Emydinorum*, novum, in quo sternum, et thorax, et ossa marginalia, suturâ tripartitâ cartilagineâ junguntur, sectionem morsum hirudinis simul-antem monstrante.

The above character suffices to demonstrate the distinctness of the species under consideration from any previously described, and the specific designation is derived from the most prominent character of the animal as yet known, and in the annular arrangement of the marginal bones.

C. ANNULIGER, n. s.

The marginal bone, whereon I base the above genus and species (and which, except a slight fracture at one corner, is perfect), is trapezoidal in shape and cuneiform in section. It presents an upper and under surface, respectively slightly concave and convex, which were shown to have been external surfaces by the clearly marked furrow which traverses them, and indicates the junction of the superficial or dermal scutes (fig. 1, *a b*, fig. 2, *c d*). The bone is bounded laterally by a jagged sutural surface, whereby a complete and rigid bony union was effected between it and the adjoining marginals, which must have constituted an encircling bony ring of an extremely rigid character, from the great horizontal breadth of the bones in question. The peculiar and characteristic feature, however, of the bone lies in its internal margin (fig. 3, *e f g*) which displays a smooth surface, indicating a cartilaginous union only, with the bones of the sternum and thorax. This inner marginal surface is obscurely divided into two areas of unequal breadth, of which the lower is broader and opposed to the sternal plate, whilst the upper and narrower surface receives the thrust of the bones of the thorax. The thorax and sternum were no doubt united by a cartilaginous suture, as a cartilaginous junction with the marginal is opposed to the idea of a rigid bony union between the bones in immediate contact with them, since a rigidly ankylosed bony ring united only by cartilage to bones themselves joined by a bony suture, could lend no additional strength, though it undoubtedly would do so supposing it to cover and defend a cartilaginous union of the sternal and thoracic bones.

The length of the external margin is 5·5 inches, which indicates approximately an animal close on 10 feet in circumference. The condition of the suture shows that the individual was not of full age, and 12 or 14 feet may probably be assumed

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as not an over estimate of the dimensions of the fully adult animal, which probably exceeded the dimensions of the largest *Chitra*, though our positive knowledge of the precise limits attained by our living Chelonian is singularly meagre and limited. That *Cautleya* was an aquatic species may be inferred from the cartilaginous union of the bones of its case, which in living species is seen in such fluviatile forms as *Cuora* and *Cyclemys* and is unknown in terrestrial forms. The opposite conclusion, however, among Chelonia cannot be drawn from the complete ossification of the body case, as *Butagur* and its allies are possessed of as completely ossified a case, though strictly aquatic, as *Testudo*, which is entirely terrestrial.

The specimen was obtained near Nila, on the Sohan river, in the Rawalpindi district, in upper Siwalik strata, and in company with remains of *Mustodon perimensis*, F. et C., *M. pandionis*, F., *Palaopithecus sivalensis*, Lyd., *Acerrotherium perimense*, F. et C., and other Siwalik fossils.

Among the collection from the same locality are fragments of a large Testudine, exceeding in size the living *Manouria*. They consist of one anchylosed pair of episternal bones, with a transverse diameter of 8·5 inches (allowing for a slight fracture) ; a single right episternal bone of a rather larger size, 2·5 inches thick and 6·25 long, and a free marginal (that is, one anchylosed to the thorax only) 3·3 broad and 4·5 long (measuring from the outer margin).

These bones would indicate an animal nearly as large as the last, and probably fully equal to it in bulk. At present, however (with no other materials), it seems undesirable to give it a name.

SKETCH OF THE GEOLOGY OF NORTH ARCOT DISTRICT, *by* R. BRUCE FOOTE, F.G.S.,
Geological Survey of India.

The North Arcot District, one of the purely inland districts of the Madras Presidency, is topographically characterized by its great irregularity of surface. Except in its south-eastern quarter, the district is extremely hilly and in some parts quite mountainous. In the west and north-west it embraces a considerable part of the high and rugged eastern scarp of the great Mysore plateau, from which many long spurs jut out far to the eastward. In the south-west it includes the northern end of the Javádi mountains and the Vellore hills. In the north it includes the well known Tripatti mountains, the "sacred hills of Trippetty," and the southern extremity of the Vellakonda (Eastern Ghâts so-called). The north-eastern corner of the district contains the Nagari mountains; and three groups of lower hills, the Sattavedu, Alikur, and Naikenpalem hills, on the extreme eastern border of the district, and a considerable number of detached hills in the gneissic country west of the Madras railway. Some of these latter, as the Maddur (Muddoor), Sholinghur, and Makrs Drúg hills, and others, are of considerable height and extent. In the south-east of the district only two detached hills need be named, those of Wandiwash and Chitpat (Chittapett).

The hydrology of the district is very simple, all the drainage falling into the Bay of Bengal and chiefly by the Pálár river, which, rising on the Mysore plateau, drains the whole southern half and greater part of the centre and west of the district. The north-eastern part feeds the Korteliar and Nagari (Naggery) rivers, and also the Narnavaram and Suvar-namukhi (Soornamookey).

The geological formations met with in this district may be conveniently classified into six groups, which may be arranged in their true order of superposition as follows :—

RECENT AND TIARY.	POST-TER-	6. Soils and subaerial deposits.
		5. Alluvial deposits ; fluvatile.
		4. Lateritic sands, gravels, and conglomerates.
MESOZOIC	...	3. Upper Gondwána series, Rajmahal or "plant" beds.
AZOIC	...	2. Kadapa series.
		1. Gneissic series, with intrusive trappean and granitic rocks.

The gneissic series, which forms the basement on which rest all the other rocks, occupies by far the larger part of the whole area of the district, and it is only in the north-eastern and eastern parts that younger rocks occur. The gneissic rocks include all the western part of the district, and form the rugged eastern scarp of the Mysore plateau already referred to (p. 187). Eastward of the plateau, are numerous spurs stretching away from it, and eastward of these again are numerous clusters of detached hills, some of considerable size and elevation, and remarkable for their bold forms and great ruggedness. These occupy the gneiss area up to the very convenient geographical line formed by the north-west line of the Madras railway, eastward of which the gneissic rocks soon disappear under newer formations, to be referred to separately further on. The gneissic area south of the Pálár shows the northern end of the Javádi mountains and the hills east and south-east of Vellore. Further to the south-east the gneiss area becomes comparatively flat, and no hills of any importance rise from its surface, the two hills of Wandiwash and Chitpat (Chittapett) excepted, which have already been named.

Returning to the north of the Pálár, the gneissic rocks are overlaid by great masses of quartzite and conglomerate belonging to the Kadapa series, which form the greater part of the detached mountains collectively known as the Nagari mountains. The south end of the Vellakonda and the sacred hills of Tripatti to the north are also formed of rocks belonging to the same sub-division of the Kadapa series.

The tremendous lines of scarp and often vertical cliffs surrounding in many parts the Nagari and Tripatti mountains give a peculiar and grand character to the local landscape.

South-eastward of the Nagari mountains lie the three hill groups before mentioned (p. 187), *viz.*, the Sattavedu, Alikur (Allcoor), and Naikempalem hills, consisting of great beds of hard conglomerates and sandstones in the Sattavedu and the eastern half of the Alikur hills, and of uncompacted conglomerates, clays and shales in the western half of

the Alikur hills and the Naikenpalem group. Some of these beds are fossiliferous, and the fossils show them to belong to the upper division of the great Gondwána system, which includes all the plant-bearing beds in the peninsular area. The fossils agree in many cases, specially with those found in the Rajmahal beds of Bengal.

South of the Naikenpalem hills are other outcrops of the "plant beds" lying between the Nagari river and the Kortelliar. South of these again and south also of the Pálár, the Upper Gondwánas re-appear in a considerable number of small patches dotted over the surface of the eastern part of the gneissic area in the Arcot taluq.

Much of the surface of the "plant beds" is masked by lateritic deposits, which	
Lateritic rocks.	overlap also in many places on to the gneiss. They do not cover much ground in North Arcot. One of the uppermost places in the superposition of the rocks, but the lowest in point of elevation over the sea level, is occupied by the alluvial formations, which are all fluvialite. Although of very limited extent, they yet offer some points of considerable interest.
Alluvial formations.	

The soils are of no special interest, but among the subaerial deposits, the enormous masses of talus which surround the mountains in the north-eastern part of the district are remarkable.

But very little had been written on the geology of North Arcot before it was	
Previous observers.	taken up systematically by the officers of the Geological Survey Department. Dr. Buchanan and Dr. Benza had given short notes on the geology of the country along the Madras-Bangalore road between Arcot and the Mysore frontier, and Lieutenant (afterwards Colonel) Baird Smith, of the Engineers, had published a paper "on the crystalline structure of the trap dykes in sienite of Amboor," entering elaborately into the questions connected with the formation of such rocks.

The Geological Survey.	The geological survey of the district was taken up in 1863 and continued in the years 1864 and 1865, the work being undertaken by Mr. C. Æ. Oldham, Mr. W. King, and the author.
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About two-thirds of the district was surveyed, the greatest part being done by Mr. Oldham, who examined the south-eastern and central parts, while Mr. King surveyed the north-western corner. The eastern part north of the Pálár, and the Vellore and part of the Gudiattam (Goriattum) taluqs in the south-western corner of the district, were surveyed by the author.

The Chittur, Palamaner, part of the Gudiattam taluqs, and the Punganur zemindari, though not surveyed, were traversed in several directions by Mr. C. Æ. Oldham and the author, and sufficient is known of them to form an idea of their general geological features.

Of the information gained by the geological survey part only has been	
Its results how published.	hitherto published. So much of the eastern part of the district as lies within the eastern half of sheet 78 of the Indian Atlas has been illustrated in a geologically colored copy of that half sheet printed in 1872. The features of the northernmost part of the district, including the Tripatti and Nagari (Naggery) hills, were shown in the small-scale general

map of the region occupied by the Kadapa and Karnul rocks, published with Mr. King's memoir on those rocks in 1872,¹ and the component rocks described in that memoir.

Of the country illustrated in the geological edition of sheet 78 (eastern half), only part has been described in any of the publications of the Geological Survey hitherto issued.

The part described included the south-eastern half of the Wallajah taluq, the eastern part of the Karvet Nagar zemindari, and the south-eastern part of the Calastri zemindari; the description of these was given in a Memoir by the author published in 1873.² Brief references to the three tracts just named and to the Nagari region had been published rather earlier by Mr. King and the author in two papers in the *Records of the Geological Survey of India*, under the respective titles, "*On the Kuddapah and Kurnool Formations*" (1869), and "*Notes on the Geology of the neighbourhood of Madras*" (1870). Some of the geological features of the North Arcot country were also referred to in a paper "*On the occurrence of stone implements in the formations in various parts of the Madras and North Arcot districts,*" published in the *Madras Journal of Literature and Science* for 1866 by the author, with notes by Mr. King. The same and some other geological features of the North Arcot country were touched upon in another paper "*On the distribution of stone implements in Southern India,*" read by the author before the Geological Society of London in 1868 and published in the *Society's Journal* for the same year.

The Memoir "*On the Geology of parts of the Madras and North Arcot districts,*" &c.,³ above quoted gave a rather full account of the Upper Gondwana and overlying lateritic rocks in the Arcot district, as also of the alluvial valleys of the Nagari and Nurnavaram rivers. The information there given will be repeated in a somewhat condensed form in these pages, together with a good deal of new matter not yet published, owing partly to the non-completion of the survey of the district, but mainly to the premature decease of Mr. Charles Æ. Oldham.

The only geological map on which North Arcot had been represented on an intelligible scale prior to the publication of the geological edition of sheet 78 was Greenough's general geological sketch map of India, published in 1854, a laborious but in many respects untrustworthy compilation. The features of the North Arcot country are laid down very incorrectly in this map, the data from which it was compiled being utterly insufficient for the purpose.

The older rocks of the district being in great measure the source whence the materials for the formation of the newer ones were derived, it will be most convenient to describe the several groups recognized in their ascending order of sequence.

¹ *Memoirs Geological Survey of India*, Vol. VIII.

² *Memoirs Geological Survey of India*, Vol. X, pt. 1: "*On the geology of parts of the Madras and North Arcot districts lying north of the Pálár river and included in sheet 78 of the Indian Atlas.*"

³ *Memoirs Geological Survey of India*, Vol. X, pt. 1.

GROUP I.—*The Metamorphic or Gneissic rocks.*

It has already been pointed out that the rocks belonging to this group occupy by far the greatest part of the whole district. The predominant varieties are the massive obscurely bedded ones known among geologists as granite-gneiss and syenite-gneiss. The well-bedded fine-grained schistose varieties are much less frequently met with than in other parts of the great gneissic region, as in the Trichinopoly, Salem, Madras, and Nellore districts, but they do appear locally among the coarse granitoid varieties, and occurrences of them will be described further on.

As in all the gneissic regions, the rocks show abundant signs of having been much disturbed, contorted and uptilted since their original deposition, and finally forced into series of great synclinal and anticlinal foldings, the edges of which may in some cases be easily traced along great distances.

A study of the direction of the edges or outcrops of the beds, technically called the "strike" of the bedding, shows that in the south-eastern part of the district the beds have a strike from south-south-west to north-north-east, but as they are traced northward they are found to trend till they run north-south, which is the prevailing strike in the central parts of the district. If followed into the extreme northern part, they will be found to have trended to north-north-west. This change in the strike is part of a great curve formed by the metamorphic rocks in the latitude of Madras, and affecting the whole gneissic series eastward of the Mysore plateau.

In describing the general appearance of the central part of the district, Mr. Oldham in his notes remarks very aptly: "Speaking generally, the whole area might be said to be one of quartzo-felspathic gneiss, commonly syenitoid or granitoid." "When, however, I say quartzo-felspathic, I do not mean to imply that these minerals only constitute the rock, but that they preponderate largely, and that the hornblende and mica which also enter into its composition play a very subordinate part, except in occasional bands." These remarks apply equally well to the general features of the rugged flanks of the plateau edge as seen in the Sainegunta and Mugli Ghâts and at Satghur, and to the whole western part of the district in fact. They apply also fully to the gneiss of the eastern side of the district north of the Pálár, but less so to the rocks of the south-eastern taluqs. Here and around Vellore the well bedded varieties are rather more largely developed, and they are much less largely quartzo-felspathic in constitution.

Commencing in the western part of the gneissic area, the eastern edge of the Mysore plateau consists mainly of coarse granitoid gneiss, which is well seen in the hills west of Ambur, at Satghur, and thence generally on the Sainegunta and Mugli Ghâts leading to Palamaner, all around that place and northward of it, very conspicuously in the Gam Kondas and other hills stretching away to Avulpilli Drug. The same description applies to the whole of the country between Vellore and Chittur, and to the very hilly tract lying between the Poiney river and the Madras railway. East of the railway too the granitoid gneiss extends under the younger Kadapa and Gondwána rock series.

In the southern part of the gneissic area, forming the northern end of the

Javádi mountains, are great bands of granitoid gneiss, some of them remarkable for their coarseness of texture, which is blotchy and often markedly porphyritic, *e. g.*, the rock forming the mass of the Palikonda (Policondah) mountain and of the Vániambádi¹ trigonometrical station hill, some three or four miles to the south-south-east. Similar "blotchy" gneiss is of very common occurrence elsewhere. In the Palikonda hill the rock is of a hornblendic variety, and of grey color.

A remarkably handsome variety of porphyritic hornblendic granite gneiss of rich green and pink colors occurs at the western base of the Nagari (Naggery) Nose mountain, and is exposed in several cuttings along the Madras railway (north-west line). Masses and boulders of this variety are to be seen included in large numbers in the basement conglomerate of the Upper Gondwána rocks in the Pyanur area south of the Nagari river.

The contrast between the rich dark-green hornblendic matrix and the large pink or salmon-colored crystals of orthoclase makes the rock a very handsome example of a typical porphyritic granite gneiss.

A by no means uncommon form of the granite gneiss is one in which the beds Quasi "brecciated" include masses of what appears to be an older gneiss, sometimes micaceous, sometimes hornblendic. The included masses present generally sub-angular forms, but others are well rounded, as if they had been boulders, and others again unquestionably angular, so that the mass looks sometimes conglomeratic, sometimes breccoid. In other places again, and often within the same beds and at no great distance, the inclusions have the appearance of having been altered by concretionary segregation. The included masses are mostly of finer grain and of more highly micaceous or hornblendic character than the surrounding masses. There can be little doubt that in some cases the included fragments are really remains of older rocks, and the whole rock a true breccia or conglomerate. In other cases, however, the inclusions are in all probability mere local aggregations of the prevalent or most striking mineral. An example of this latter kind is to be seen in the Chikeli Drug hill, a little to the south-east of Kaneambadi pass, nine miles south of Vellore. Good examples of this quasi-conglomeratic and brecciated structure may be seen to the west of the Nagari railway station, in the low hills close to the railway at Ranawaram near the Sholinghur station, and in the southern part of the district and to the south of Chitpat (Chittapett), and at Erumbaucum, eight miles to the east-south-east of Arcot, and on the eastern side of the district at Gudinaucarur, six or eight miles east of Wandiwash.

Of the more schistose bands of gneiss, the most noteworthy is the great Schistose band of Kai- micaceous band forming the Kailasagiri peak, six miles lasagiri. south-west-by-south of Vellore, which rises in a bold peak to an elevation of 2,677 feet above sea level. This gneiss is compact and massive in structure, and has been uptilted to a very high angle, the true dip of the beds varying from 80° to 85°. The strike of the beds corresponds with the direction of the highest part of the ridge and is north 5° east.

The very coarse garnetiferous micaceous gneiss of Chikeli Drug (already

¹ This place must not be confounded with the town and railway station of the same name on the northern boundary of Salem district.

referred to) extends northward into the Vellore hills, and forms a considerable part of the main ridge of the hill group.

Beds of magnetic iron occur here and there in the south-west corner of the district, *e. g.*, to the south of Gudyátam (Goriattum), half a mile south of the great tank, and again two and a half miles west of Vellore railway station. These beds are small, but interesting, as there can be no doubt that they are representatives of some of the numerous beds occurring south of the Javádi hills in Salem district. Others of these richly ferruginous beds are in all probability represented by various quartzose gneiss beds, very strongly iron-stained, which occur in this quarter. The quartz of these beds is stained of purplish or reddish color, and frequently shows a brown ferruginous incrustation in the cavities between the laminae, as also numerous little cavities in the lamination which appear once to have been filled by some mineral or other now wanting. These beds have a striking resemblance to the poorly ferruginous parts of many of the typical magnetic iron beds of the Salem region. Good examples of these iron-stained beds are to be seen in the Vellore hills and in the large detached hill three miles south of Vellore.

Probable representatives of the magnetic iron beds are also the numerous quartzo-ferruginous beds noted by Mr. C. Æ. Oldham in the Arcot and Wandiwash taluqs. His notes unfortunately do not mention the form in which the iron occurs. The geographical situation points, however, strongly to these being continuations of the numerous magnetic iron beds occurring to the east and north of the Kabroyen mountains in South Arcot, beds which themselves are unquestionably north-easterly extensions of some of the great magnetite beds of Salem district. Associated with these quartzo-ferruginous beds in the south-eastern part of the district are also numerous beds of hornblendic ferruginous gneiss.

These occur chiefly in the tract of country between Arcot and Wandiwash. To the eastward of this hornblendic band lies a broad zone of highly granitoid quartzo-felspathic gneiss which extends to the boundary of the Chingleput (Madras) district; the great Wandiwash hill belongs to this band.

In the more granitoid region north of the Pálár hornblendic forms are much less common than the quartzo-felspathic forms of gneiss.

Ferruginous beds were noted by Mr. C. Æ. Oldham, chiefly near the Poiney river, *e. g.*, north of Chel Kempollian; south-west of Bomupilli, eight or ten miles to the north-north-westward; and lastly, to the north of Maimandalum, on the western side of the Poiney river.

Talcose beds occur only in a few places. Three were noted by Mr. Oldham, all of small importance. They occur at Damavapak (Damarpauk), north of Arni, a little to the west of the

road to Arcot, at a place on the left bank of the Poiney river, eight miles north-north-west of Ranipet cantonment, and lastly, a little to the south-east of Murta Pilli and twenty miles north of the last named locality. An extremely quartzose band of gneiss is seen to the north-west of Sholinghur and north of Randareddi (Rundaddy).

In a district where so large an area is occupied by intensely granitoid gneiss, its characteristic features are of course to be seen to great advantage in many places, particularly along the two lines of railway diverging from Arconum junction. Especially characteristic are the hills of Maddur Drug and Trittan on the north-west line, and those of Sholinghur, Nelacontriapetta, and Gudyátam (Goriattum) on the south-west line; all of these show great bare masses of rock with tors, and here and there great precipitous cliffs.

Of the tors the two most remarkable groups are both near Nagari; the one, between the railway and the foot of the Nagari mountain close to the northern end of the pass traversed by the old high road to Kadapa; the other, at Neddiem (Neddum) on the north bank of the Nagari river, four miles above the railway bridge. Both groups are of great size and height and form conspicuous objects from considerable distances.

A very common accessory mineral occurring in the granite gneiss is epidote, in its pale apple-green variety known as pistacite; it occurs scattered through the general mass of the rocks, or in minute veins, and very commonly as a thin coating to planes of jointing.

ROCKS INTRUDED INTO THE GNEISSIC SERIES.

The crystalline rocks intruded into the gneissic series are referable to four groups—granite veins, felspathic porphyries, quartz veins, and trap dykes. Of the four groups, the last is by far the most important, and the first the least so, granite veins being very rare and of small size; the trap dykes, on the contrary, extremely numerous, and many of them of large size, and forming important features in the landscape in very many parts of the country.

The granite veins seen in North Arcot are, with one exception, of quite small size, and all appear to consist of a binary rock, in which only quartz and felspar are recognizable. Some of them contain a few scattered crystals of epidote as an accessory mineral.

Numerous veins of very small size of dark salmon-red color, and highly felspathic in character, occur in the gneiss to the south of the railway station at Vellore, and a larger but still small vein of the same kind occurs at Vajur (Vanjoor), two miles south-west of the railway station.

The most important granitic protrusion noted is a vein occurring at Tarur (Turroor), eight miles east of the great Kaveripak (Covrepauk) tank, and about ten miles south-west of the Arkonum railway junction. It forms a bare and generally smooth ridge one and a quarter mile long, about 40 feet high at its summit. It is a binary quartzo-felspathic granite of coarse grain and full of minute cracks.

The very handsome green and pink syenitoid rock occurring at the western base of the Nagari mountain has been referred to before (p. 192) when treating of the gneissic rocks, but the rock is so extremely crystalline that it might easily be taken for a truly intrusive rock, and the more so as the position it occupies with reference to the surrounding unquestionably gneissic rocks is rather obscure.

The felspathic porphyries occurring in North Arcot district are very interesting, as being the only examples of this species of rock known in the south of the peninsula. Several very fine veins of this porphyry occur south of the Palikonda mountain (p. 192), and two of them may be traced for several miles in an east-to-west direction. In width they vary from 20 to 50 feet, and vary in color from smoky grey to pale drab, when freshly broken. Numerous prisms of flesh-colored or white felspar from $\frac{1}{8}$ th to $\frac{1}{2}$ an inch long are included in the felspathic matrix. Small acicular crystals of dark green hornblende are less frequently included. The felspar crystals often stand out in great perfection on the weathered surfaces, and in some parts of the veins the included crystals form nearly half the mass. A little distance south of the western end of these two veins is a third in which the included small dark green acicular hornblende crystals are numerous, but the felspar crystals of rare occurrence in the greyish-white felspathic matrix. The felspar crystals are white and show very faintly.

On the east flank of the Palikonda mountain is a drab or pale buff-colored vein which appears to cross the mountain, for a precisely similar rock shows on the west flank. In this case the included crystals consist of felspar and quartz. Two other small veins of the same character appear on the west flank close to the north-west corner of the mountain, and a third of smoky grey color, with reddish felspar crystals, runs nearly east-to-west for two or three hundred yards parallel with the high road to Bangalore on the north side of the mountain.

Another small vein of the felspathic porphyry occurs in the centre of the valley west of Kailasagiri peak (south-south-west of Vellore); it is of the same character as those just described.

In point of age these porphyry veins seem to be newer than the trap dykes they cut in their course. Unfortunately this point could not be definitively settled owing to the presence of soil and debris at the points of intersection.

Quartz veins are not very common. A few were noted by Mr. Oldham in the Wandiwash and Arcot taluqs; they are of good size (two to three miles in length), but offer no special features of interest; their course is either north-east-by-east to south-west-by-west, or north-west-by-north, south-east-by-south.

The trappean rocks seen in North Arcot district all occur in the shape of dykes, often of great size and length, and forming important features in the landscape. They occur commonly in all parts of the district, and in the central part occur frequently in very large numbers.

The great majority of the dykes consist of coarse hornblendic trap, a form of greenstone, and there is in very many cases a direct proportion between the size of the dyke and the coarseness of the rock composing it. Many of the dykes are markedly porphyritic in structure, including numerous crystals of felspar in a hornblendic or hornblende-felspathic matrix. If classified according to the directions of their courses, the dykes will be found referable to two great systems, of which the one runs north to south, roughly speaking, and the other east-by-north to west-by-south. In the former, the course is less constant, and varies by

5° or so east or west of north. A relatively small number of dykes does not come under either of these two systems, but they offer no special differences in mineral character, or otherwise to require any detailed notice. There is no marked difference between the trap rock forming the members of the two systems, and they appear to belong to the same geological age. Both agree in being older than the Kadapa system of rocks which they nowhere intrude into. The relations of the dykes at their crossings, are obscure in all cases in this district, but the intersections of other dykes of precisely similar rock and running in corresponding directions in more northerly parts of the gneiss area, *e.g.*, in Bellary district and the Raichur doab, appear to show that the filling up of both sets of fissures by the irruptive material was simultaneous, no difference or change of any kind being observable. Very large and important dykes, such as the great dyke at Sholinghur and some in the Maddur (Muddoor) and Trittani hills, rise to heights of several hundred feet above the surface, and form bold and striking ridges and crests.

Some of the dykes, such as the Sholinghur dyke and the Permalrajapet dyke, some eight miles to the east, are distinctly and strongly magnetic and affect the compass needle greatly. This phenomenon was also noticed in the dyke lying to the west-by-south of the village of Poiney, but not elsewhere.

Excepting a little pale iron pyrites (marcasite) no accessory minerals have been noticed in any of the dykes. The pyrites were seen in some of the dykes traversing the hill east of Vellore town.

Well characterized examples of porphyritic greenstones are to be seen to the south-east of Ranipet cantonment, and in the railway-cutting south of Pudi station on the north-west line of the Madras railway. As a rule, with few or no exceptions, the greenstone weathers more slowly than the surrounding gneissic rock, and consequently the dykes form ridges running over hill and dale, and from their dark color contrasting strongly against the gneiss.

The courses of many of the dykes may be followed for twenty or thirty miles or even more, and the larger ones have a width of from 50 to 100 paces. The network formed by these multitudinous dykes is one of the most remarkable displays of trappean injection known in any country.

THE KADAPA SERIES.

The representatives of the Kadapa series are confined to the north-eastern corner of the district, where they form, as already pointed out, the main mass of the Nagari group of mountains, the Tripatti hills, and the extreme south end of the Vellakonda range. The remarkable and highly picturesque scenery of this region is due to the great mural scarps into which the massive quartzite beds have been worn.

The Nagari mountains form several outliers detached from the main area of the Kadapa rocks, of which the Tripatti hills and the end of the Vellakondas form the southernmost extremities.

The principal outliers are four in number, the Nagari Nose mountain forming the most southerly of the number. North of this is the Narnavaram ridge, a long

narrow ridge lying north-east of the village of Narnavaram, and not to be confounded with the Narnavaram peak, which forms the southern end of a large outlier which includes the Saddashemallai or Sathuskonda, the highest member of the Nagari group, and the mountains south of Kálabástri (Calaetsy). The fourth large outlier includes the Ránsagiri and the Kambákam (Cumbaucum) Drug mountains.

Many of the quartzite beds which rest on the gneiss in marked unconformity are coarsely conglomeratic, including pebbles of gneiss, quartz, and occasionally of ribbon jasper. The quartzites are generally very massive, and semi-vitreous in texture, and occur in thick beds which often show but little lamination. The surface of some of the beds is often covered thickly with small annular markings, as if they had been stamped all over with an ordinary wad-cutter. No satisfactory explanation of the cause of these markings had yet been offered. In some beds the rippling caused by current action has been beautifully preserved.

The prevalent colors of the quartzites are pale greys and drabs, all weathering to shades of buff or pale orange. The principal lines of scarp face the south, *e. g.*, those of the Nagari Nose, the Narnavaram peak, the Saddashemallai, and the Tripatti mountains, but very fine east and west scarps are seen on the Ránsagiri. The three scarps first mentioned are in many parts quite vertical, and form perfectly bare walls of rock from a few hundred to over a thousand feet in height. The smaller outliers show some of the lowest beds, but are of no special interest.

The whole of the beds exposed in the North Arcot district belong to the second lowest of the divisions recognized in the Kadapa series by Mr. King¹ and called by him the Nagari series, a yet lower series underlying the Nagari beds having been recognized by him further north near the Papagni river in Kadapa district.

The most southerly recognized outcrop of the Kadapa beds is the Nagari Nose mountain, but it is not improbable that some large detached masses of quartzite occurring at the base of the Gondwána rocks at Naikenpalem, eight miles further south-east, ought to be regarded as relics of the basement bed of the Nagari group. These masses of quartzite will be referred to again further on.

THE UPPER GONDWÁNA SERIES, RAJMAHAL GROUP.

The great series of rocks known under the name of the Upper Gondwána, which occupy a very important position in the northern half of the peninsular area, are represented in the Madras region by considerable formations of great interest, because they contain fossil plants, some of which are identical with those occurring in the Upper Gondwána formations of the Rajmahal hills in Bengal.

Their representatives in North Arcot occur in two positions, one north, the other south of the Pálár. In the first we may conveniently distinguish three localities, the Sattavedu, the Alikur (Alcoor), and the Pyanur areas; in the second there are some twenty-five small patches scattered widely over the surface of the gneissic area in the Arcot taluq, a few miles south-west of Con-

¹ See Memoirs Geological Survey of India, Vol. VIII.

jeveram. The most important and the greater number of these patches lie around the great Mámdur (Maumdoor) irrigation tank, and hence the group may be conveniently called the Mámdur group. Three small outlying patches occur twenty miles further to the south-west in the Arni zemindari. This group of small patches are evidently the remnants of a once extensive spread of the Upper Gondwána rocks, which, in all probability, was continuous with the beds of the same age to the north and north-east, and very likely also extended far enough southward to join the Utatur (Ootatoor) "plant beds" in Trichinopoly district.

Great denudation, especially in the area south of the Palár, beginning probably in precretaceous times, separated the Gondwána rocks into the many detached outliers now enumerated, while their surface is largely obscured by the overlying younger lateritic and alluvial formations.

As before mentioned, the Upper Gondwána beds of the Madras region have been divided into two groups, called after the localities in Division into two groups. which best developed, the *Sattavedu* and *Sripermatūr* groups; the division is chiefly based on petrological differences, the actual stratigraphical relations being very obscure and somewhat doubtful owing to the insufficiency of existing sections.

The *Sattavedu* group, which consists mainly of coarse, well consolidated conglomerates and sandstones of great thickness, forms the mass of the *Sattavedu* and the northern and eastern parts of the Alikur hills, while beds of uncompacted conglomerate with intercalated clays and shales appear to underlie the hard *Sattavedu* beds in the western and southern parts of the Alikur hills. Unfortunately no section exists (or existed) showing the two sets of beds in actual contact, hence their stratigraphical relations are still doubtful.

The soft beds have been referred provisionally to the *Sripermatūr* group on petrological grounds, the resemblance of the softer rocks being much stronger to the rocks found in the *Sripermatūr* outcrop in Chingleput district, than to the coarse and compact conglomerates and sandstones of the *Sattavedu* and eastern Alikur hills.

The whole of this outcrop is made up of alternate bands of hard conglomerates and sandstones, many hundred feet in aggregate thickness, and of more or less red color. The conglomerates are made up of large well rounded smooth quartzite pebbles, with a small number of similar pebbles of granite gneiss, the whole strongly cemented by a matrix of variable character, sometimes argillo-ferruginous, ferrugino-arenaceous, or more rarely siliceo-calcareous. The sandstones are mostly rather gritty in texture, and contain here and there a few plant remains, among which Mr. King found a frond of *Dictyozamites indicus*, one of the most characteristic Rajmahal plants. The beds have a generally eastward dip at moderate angles. The area of the outcrop is nearly co-extensive with that of the hill group, and measures about sixteen miles.

The Alikur area is separated from the foregoing only by the narrow alluvial valley of the Narnavaram river, under which the beds are doubtless continuous. The eastern half of the Alikur hill group consists of hard conglomerates and sandstones, apparently continuations of

the beds forming the south-western part of the Sattavedu hills. Like these they have a more or less easterly dip, and disappear under the lateritic beds, which lap round the eastern foot of the hills, and which, together with the great talus which has accumulated on the base of the slopes, completely obscure all the relations between the lower and upper rocks. No fossils were found in the Alikur hills. The hard beds occupy only about a third of the area of the Alikur outcrop, the remainder being formed of the soft beds assumed to belong to the Sri-permatum group, and which, as already mentioned, appear to underlie the hard beds conformably. No section was found showing these two dissimilar series in contact where they approach each other in the centre of the Alikur hill group, but as far as the rounded outlines of the hills at that point serve to guide the eye, there is an undoubted dip of the softer beds under the hard conglomerate. No sign of any fault could be traced, but from the peculiar nature of the case, a fault of great importance might well exist, and yet be completely hidden by the vast quantity of debris and talus which everywhere almost cumber the surface even of steep slopes. The nearest visible approach of the two series is a short narrow east and west ridge abutting at right angles against the hard basement conglomerate of the Sattavedu series, which here forms a conspicuous north and south ridge parallel with several of similar character further east, each representing a great conglomerate bed. The valleys running down north and south from the cross ridge are the two principal ones in the central mass of the hills, and their depth, which is considerable, is due to the greater softness of the underlying beds as compared with the overlying set.

The soft beds so frequently named consist of conglomerates, gritty clays, and shales of white or grey colors. Even the coarsest conglomerates at the very base of the series are uncompacted and soft, the enclosed pebbles and boulders of gneiss and quartzite merely lying embedded in very friable more or less clayey grit consisting of quartzose debris of gneissic origin. The slopes of the hills composed of such soft beds are deeply covered by debris, while but few of the rain gullies descending from higher slopes penetrate sufficiently to expose the rocks *in situ*. The Naikenpalem hills, which occupy the southern part of the Alikur area, consist, as far as seen, entirely of the soft beds which have trended round from a north and south strike in the Alikur hills to one running west-north-west to east-south-east.

Numerous plant remains were obtained from a clay bed exposed in one of the principal rain gully sections east of Naikenpalem village. Amongst the remains were parts of *Teniopteris*, *Dictyozamites*, *Ptilophyllum*, &c., all characteristic Rajmahal plants. Unfortunately the specimens, which are beautifully distinct when freshly extracted, are utterly ruined by the shrinkage of the wet clay as it dries.

Near the village of Naikenpalem the basement bed includes enormous masses of conglomeratic quartzite, some of them from 800 to 1,000 cubic feet in bulk; these are very probably relics of the basement bed of the Kadapa series, which is so generally represented a few miles to the north-west and north in the great scarps of the Nagari mountain and the Ramagiri. These great quartzite masses are not seen resting actually on the

gneiss surface, but it can only be a few feet below the local surface of the slope; it is only reasonable, therefore, to look upon them as ruins of the once existing conglomerate bed forming locally the base of the Kadapa rocks, which was nearly all removed by denudation. In view of the enormous amount of denudation the shapes of the Nagari mountains show them to have undergone, there can be no difficulty in accepting this solution of the problem. If the blocks be not, however, really *in situ*, their existence in their present position is even more remarkable, as no known agency, but that of floating ice, can explain their presence. The appeal to glacial agency in such a southerly latitude would not be justified except on the very strongest evidence.

The character of the rocks in the Pyanur area changes slightly, the included boulders and pebbles in the conglomerates are more frequently of gneissic origin and less exclusively of quartzite. The Pyanur area. They are embedded in equally soft and uncompacted beds. Fossils are very rare; none were found except in a friable sandstone exposed in the left bank of the Nagari river opposite Chittapuram, a little below the junction of the Tritani river. Fragments of *Teniopteris* and *Dictyozamites* were here obtained.

The basement conglomerate in many parts of the Pyanur area was deposited around and includes large water-worn masses of gneiss forming boulder beds similar to those occurring in the base of the plant beds at Utatur and elsewhere in Trichinopoly district, and similarly at various places in the Ongole group of outcrops in Nellore district.

The hard white and mottled shales so typical of the Sripermatpur group in its proper basin do not occur in any of the outcrops in the Arcot district, but some of the clays exposed in the south-eastern corner of the Alikur area show signs of passing into a shaly condition, and appear to do so further to the north-east in the valley of the Alikur nullah.

Outcrops south of the Pálár.—The petrological features of the southern or Mámdur group of outcrops, as well as their geographical proximity, justify their being assigned to the Sripermatpur division of the Rajmahal beds. As they were visited only by the late Mr. C. Æ. Oldham, it will be better to quote the description, as far as possible, in his own words as given in his notes.

The three most westerly outcrops, which have already been mentioned as lying about twenty miles south-west from the Mámdur group, Thechur outlier. are situated close to the village of Thechur, seven miles south of Arni. Here to the south-west of the village occurs a "greenish-yellow shaly sandstone," which "is also dug out from wells in the village." "East of the village I noticed another minute patch."

Of the patches forming the Mámdur group, Mr. Oldham remarks in his notes: "At Contcantandalam, the most easterly of these localities, Contcantandalam. several wells and bowries, in and near the village, expose about 12 feet of these beds," which are chiefly a soft yellow sandstone thick-bedded, but in the lower portion some harder compact beds occur; and a coarse conglomerate containing numerous pieces and pebbles of quartz and gneiss in a hard silicious matrix has been quarried to some extent from under the soft beds.

After mentioning a narrow and thin slip of hard ferruginous sandstone close to the ford by which the Conjeveram-Wandiwash road crosses the Pálár, Mr. Oldham describes the interesting outcrop at Doshi (a mile and a half to the south) thus:—"This locality and its immediate neighbourhood, though not affording even a single tolerable section, yielded to me the great majority of the fossil specimens, all plants, which I succeeded in procuring from this series of beds." "In a small tank west of the village I noticed a little yellow sandstone in flat beds just appearing above the surface of the water when low, and from the bund of this tank, which is largely composed of the pieces of this and other beds thrown up when it was dug, I succeeded in obtaining numerous plant remains." "I could not discover a trace of mollusca or other animal remains, but in some of the beds of sandstone the plant remains are very abundant."

"Until they have been more carefully examined and compared, I cannot attempt to do more than indicate their general character, which is very similar to that of the Rajmahal flora, presenting *Palæozamia* (*Ptilophyllum*), *Tæniopteris*? *Stangerites* (*Angiopteridium*), *Pecopteris*, and *Sphenopteris*." "I obtained also specimens of circinnate vernation of ferns. These remains occur in great abundance, principally in thin-bedded yellow sandstones, but some of them also in a coarser thick-bedded sandstone." "This strip of sandstone has its limits narrowly defined by the appearance of gneiss *in situ* closely on the east, north, and south, and at no great distance on the west also."

"About four miles west of Doshi is the best section seen of these beds.

This is exposed in the old supply channel which runs from the river Pálár near Umiaveram to the large Mámdur tank, in the banks of which and the small watercourse adjoining a fair section is exhibited, showing a greater thickness of beds than I was able to discover in any other locality." "Proceeding southward along the channel we get the following section. The first (lowest?) bed seen is a coarse white felspathic sandstone with small pebbles of quartz, from 3 to 4 feet in thickness, rather soft and scarcely consolidated, at least superficially. I could here detect no organic remains whatever. Over these lie about 3 feet of a finer yellowish sandstone with minute shaly partings of a greyish-white color." Above this are 5 feet of a hard ferruginous sandstone, the uppermost bed of which has a curiously tessellated appearance due to concretionary structure, assuming generally a pentagonal arrangement. All these beds have a low dip of 2° or 3° to the south and south-south-west. "Passing onward the section in the channel is broken and obscured by soil, &c., but the missing portion seems to be, at least in part, supplied by the smaller gullies, watercourses, &c., on either side, which show a few feet in thickness of yellow and white sandstone apparently overlying the ferruginous bands and dipping south-by-west at an increasing angle. Proceeding still southward along the channel, we come upon a hard brown ferruginous sandstone dipping south-south-west at 32°. Of this only 2 feet appear, and over this from 20 to 25 feet of a soft rather coarse yellow sandstone with a few harder ferruginous partings, all dipping south-south-west at from 30° to 35°. Over this with a dip in the same direction, but at gradually decreasing angles,

are rather coarse clunchy yellow sands, thick-bedded and only moderately consolidated. Of these about 25 feet appear overlaid by about 10 of thinner-bedded yellow sandstones of much finer grain with thin greyish shaly partings. These are apparently the highest beds¹, shown in this section, as on proceeding along the channel we find them turning up with a considerable dip of 25° to 30° to north and north-by-west." From under these again appears the coarser thick-bedded yellow sandstone which continues to show along the channel for a distance of about 200 yards, with here and there some of the thinner beds appearing in the banks above. Still following the channel, as it turns south-east and east-south-eastwards, these coarser beds continue to appear, having a rolling dip to the north-north-west." From under these rises with westerly dip a strong brown ferruginous sandstone which only shows for a short distance, and is the last and lowest bed seen in this direction, disappearing at a point due north of Namdi (Naumdee), a quartzo-hornblendic gneiss appearing a very short distance to the east. A yellow sandstone very similar to the upper beds of the section just given appears in bowries and in a little watercourse north-west of Namdi.

The small outcrop west of Tallicalli and north of the channel section just described shows coarse pebbly ferruginous sandstone. The outlier west-by-north of Tripnagad and that south of Umiaveram show coarse, white felspathic sandstone, associated, in the latter case, with a little thin-bedded ferruginous sandstone of brown color. At Cutanur, two miles to the west of the last-named outlier, a greenish-yellow somewhat shaly sandstone underlaid by a coarser yellow felspathic sandstone is exposed in well and tank sections. A coarse ferruginous sandstone forming a small patch at the north end of the Manapakam tank, four miles south-west of Cutanur, is the most westerly extension of the Gondwana rocks in this quarter.

Three miles further south-east and east of the village of Asuapetta, and again a mile to the south of the village, "we find patches of hard conglomeratic sandstone containing large pebbles of quartz. This is superficially ferruginous and of a reddish-brown color, but when freshly broken of a dull grey. It lies in thin beds on the surface of the gneiss."

Proceeding south "along the road between Asuapetta and Trivatur, we cross four distinct patches of sandstone, in the most northerly of which a tolerably good section is exposed in a supply channel running in to the tank at Jaderi (Bathary)". Here resting on the surface of the gneiss is a hard very silicious close-grained sandstone, but frequently containing large pebbles of quartz. Of this there is a thickness of several feet, showing only at intervals and not well seen. Above this, passing east along the channel, we find a coarse felspathic sandstone of no great thickness (2 to 3 feet),

¹ "From these highest beds I procured the only specimens of organic remains that I was able to secure from this locality. Owing to the soft, crumbling nature of the rock, much increased by heavy rains which had fallen recently, it was almost impossible to obtain specimens that would bear carriage. Several which I extracted came to pieces in my hands. Those which I succeeded in carrying away were *Palaeozamia*? (*Ptilophyllum*) and *Pterophyllum*? I noted also *Taniopteris* and *Pecopteris*."

with locally a fine grey shale, in which some fragmentary stem markings were noticed. All these have a low dip of 2° to 3° east." Above all is a ferruginous sandstone, 1 to $1\frac{1}{2}$ feet thick and of rather coarse texture.

The other three patches which are seen crossing the road consist of a hard Small outcrops north superficially generally ferruginous sandstone, similar in of Trivatur. character to the lowest bed of the above section. A patch of similar beds covered by a little yellow sandstone occurs east of the road about two and half miles north of Trivatur. Between three and four miles north-east of Trivatur and east of Perintur occurs a little hard grey sandstone, about 10 feet thick and weathering of a reddish-brown.

Three miles to the north close to Marianur, a large amount of debris of a reddish ferruginous sandstone covers the ground, and close to the village on the south this is seen *in situ* overlying a coarse brown felspathic sandstone, of which but little is seen, though it has been thrown up in considerable quantity from well and tank sections. In the village a tolerably hard yellowish-brown sandstone is dug out of bowries (large square wells) and has been used to a small extent for building. A similar brownish-yellow sandstone is also dug out at Shamanguri, two and half miles to the north-west.

A few more small patches might be referred to, but they offer no special characters of interest.

The numerous patches just referred to are, without exception, of small size, the largest not being more than two miles long by one in width at its widest part, and the great majority greatly less in dimensions.

THE LATERITIC FORMATIONS.

Of the numerous spreads of the lateritic rocks which fringe the eastern coast of the peninsula between Latitude $13^{\circ} 50'$ and $11^{\circ} 20'$ north, only a few extend inland sufficiently far westward to come within the limits of the North Arcot district. There is, however, abundant evidence that these rocks had formerly a much wider westerly extension, and that their present western limits are boundaries of denudation and not of deposition. The chief outcrops of them occur along or close to the eastern boundary of the district, and are in most cases seen to rest upon the Upper Gondwana beds, to which, however, they are markedly unconformable, and in many cases they overlap on to the gneiss. All the outcrops of importance lie to the north of the Pálár.

The most southerly patch of lateritic beds requiring notice lies between the north bank of the Pálár and the alluvium of the Kortelliar, about twelve miles east of Arcot town. It is in reality only the extreme western end of a very large lateritic area which occupies further eastward nearly the whole of the Conjeveram taluq. The prevalent rock here seen is of a red sandy variety with scattered patches of ferruginous gravel.

To the north of the Kortelliar the laterite occurs in the form of an enormously coarse shingle or generally uncompacted conglomerate, such Shingle conglomerate. as may be seen at and to the south of the Chinnamapett railway station. Further north the surface of the Pyanur area of Rajmahal beds is widely covered with an equally coarse shingle associated with large quantities

of ferruginous gravel and clay binding the whole into a semi-compact conglomerate, which is the general character of the lateritic beds further north round the base of the Naikenpalem, Alikur, and Sattavedu hills, the coarseness of the included shingle and the amount of ferruginous cement associated with it being locally of variable quantities. Where the shingle, which consists almost entirely of quartzite, attains a great degree of coarseness the ferruginous matrix is often masked to a very great extent, the peculiar vermicular cavities so characteristic of non-conglomeratic laterite are never seen, and the correlation of the two varieties as members of one and the same geological formation is made entirely upon stratigraphical grounds.

The principal lateritic areas lying westward of the eastern boundary of the district are those along the western base of the Ramagiri and the eastern base of the Nagari mountains, and some spreads in the valley of the Swarnamukhi river near the Madras railway at Karkambadi. In the two first of these areas the rock is much less coarsely conglomeratic than around the Alikur and Sattavedu hills and over the Pyanur area.

The surface of the Pyanur laterite patch is very thickly strewn with the extremely coarse quartzite shingle weathered out of the underlying conglomerate, and in many places progress even on foot is by no means easy across the great smooth and highly slippery stones. The surface is so extremely stony that great tracts remain waste. That a very flat country should be so inaccessible owing to the thickly strewn products of partial weathering of the rocks forming the surface is a very singular phenomenon.

Remains of lateritic beds are very numerous to the westward of the present westerly boundaries of the formation. Many such remains were noted as much as six or eight miles away from the nearest of the undisturbed beds, and a closer search of the country would probably show such ruins even far further in that direction. The greater westward extension of the lateritic rocks, before adverted to, is thus abundantly proved.

Proofs that the lateritic formations were, in part at least, formed since man's advent on earth are numerous met with in the North Arcot laterite patches in the form of well-shaped chipped implements of palæolithic types made of quartzite. Many of these were discovered by the geological surveyors in nearly all the lateritic patches, and in many cases also among the debris marking the sites of the now denuded parts of the old extensions, *e. g.*, among the gravelly ferruginous debris lying in the surface of the gneiss at and around the Arkonam railway junction at an elevation of more than 300 feet above sea level.

The highest elevations to which the implement-bearing lateritic rocks have been traced in this region are the neighbourhood of the Madras railway at Karkambadi, in the Swarnamukhi valley, and the westernmost slopes of the Naikenpalem hills; in the former case, the implements occur at an elevation of 370 feet above sea level, in the latter, at a probable elevation of between 500 and 600 feet. The Karkambadi beds yielded a great number of fine implements to the search of Mr. W. R. Robin-

son, C. E., Chief Engineer of the Madras Railway, when Resident Engineer at that place.

There can be little doubt that the great accumulations of well rolled quartzite shingle which rest on the southern bank of the Nagari Nose mountain and on the flanks of some of the mountains further north must, in part at least, be reckoned as of the age of the lateritic period, as they correspond closely in position and mineral character with the higher-lying lateritic beds just mentioned. The Nagari Nose shingle bed is deeply stained with iron from the ferruginous matrix which must have once surrounded the perfectly non-ferruginous quartzite shingle, for that is the only way of accounting for the deep and indelible purple-red color borne by the natural pale-colored quartzite. As now seen, the shingle suggests instantly the idea of its being an old raised beach.

The origin of the lateritic formations, owing to the total absence of all organic remains (the chipped implements being only indirectly of organic origin), is wrapped in obscurity and doubt. Three theories have been propounded to explain the existence of these formations which fringe the western and eastern sides of the peninsula from a little south of Bombay right round to Cuttack and still further north. The three theories have been discussed at some length, each having something in its favor, but they are still *sub judice*, and this is not the place for continuing the discussion.¹

They may be briefly designated as the marine, the fluviatile, and the sub-aerial. As at present seen, none is altogether sufficient to explain the various difficulties, and it is very possible that all three must be enlisted before more light can be thrown on the subject.

THE ALLUVIAL FORMATIONS.

The alluvia occurring within the North Arcot district are all of fluviatile origin, and occupy the valleys of the principal rivers, but are developed only to a very moderate extent, and would offer no points of special interest were it not that in two cases there is evidence of the rivers having changed their courses widely and formed a second series of deposits in other valleys.

The first of these cases is that of the Pálár, the principal river of the district, which now flows into the sea forty-two miles south of Madras, but which formerly flowed down what is now reckoned the alluvial valley of the Kortelliar river and entered the sea somewhere to the north of Madras, probably between Gunore and Pulicat. A glance at the geological map will show that the present valley of the Pálár is very disproportionate in size to the river, and equally that the alluvium of the Kortelliar is greatly disproportionate to its river, which now flows in a deep channel.

¹ For the discussion of these theories, the reader is referred to Mr. Foote's papers on the subject of stone implements in Southern India in the Madras Literary Journal for October 1866, the Quarterly Journal Geological Society of 1868, p. 484, and the Memoirs Geological Survey of India, Vol. X, pp. 54, &c. Also stone implements of Great Britain by John Evans, D.C.L., F.R.S., and lastly, to the *résumé* by Mr. W. T. Blanford, in the Manual of the Geology of India (Vol. I, pp. 368-370), of the facts known about the low-level laterite.

The two valleys diverge at a place about ten miles east of the town of Arcot, and a small stream (or irrigation channel) still branches from the Pálár here and flows down the Kortelliar valley for many miles and eventually joins the latter river. To this stream the natives have given the Sanscrit name of Vridacharanadi or "old milk river," the Tamil name of the main river "Pálár," also signifying "milk river." The alluvium occupying this valley consists of coarse gritty loose silicious sand of gneissic origin.

The second case is that of the Nagari (Naggery) river, which in former times appears to have fallen into the Narnavaram river, the Nagari river. just south of the Ramagiri, and close to the village of Nagloperam. The present course of the river lies down the old alluvial valley for a little more than three miles east from the railway bridge. It then turns sharply south-east, leaves the alluvium, and flows through a cutting in the gneiss about a mile and a half long and falls into the Trittani river, which joins the Kortelliar a few miles further east. In consequence of this the broad alluvial valley which runs between the Nagari mountain and the Alikur hills is now drained only by small streams and artificial channels. The alluvia deposited by the Nagari river both in its old and new valleys consist almost entirely of coarse gritty sand like that of the Pálár. No alluvium appears to be deposited at present, but the streams seem to be cutting their beds deeper and deeper every season.

No information was procurable from the natives as to the time when these changes took place, but the probability is that, geologically speaking, they are of very recent date, as may be inferred in the case of the Pálár from the name given to the channel which still falls into the Kortelliar; and in the case of the Nagari river, from the fact that the cutting through the gneiss by which the river escapes from its old alluvial valley presents every appearance of being of artificial origin, and must in that case have been the work of a people boasting some considerable civilization.

THE SOILS AND SUB-AERIAL FORMATIONS.

Of the soils in North Arcot little need be said; they appear, as a rule, to be the product of the weathering of the local rocks, or to have been brought from but trifling distances by pluvial action. The prevalent soils are red, and of these the sandy form is the most common.

Of the sub-aerial formations the only really interesting and important ones are the taluses around the quartzite-capped mountains in the north-eastern corner of the district. As already pointed out, the talus accumulations are two-fold, and consist partly of great collections of well rounded shingle referable to the lateritic period, and above them of the angular unrolled debris detached from the great scarps by atmospheric agencies, which debris here now shows the deep ferruginous stain characteristic of the lateritic shingle beds. On a greatly smaller scale, but still of considerable importance, are the talus accumulations on and around the newer Rajmahal and lateritic formations in the Sattavedu, Alikur, and Pyanur areas. These consist in both cases almost entirely of well rolled

quartzite shingle weathered out from the many important conglomerated beds occurring in both series.

ECONOMIC GEOLOGY.

The information on this branch is not so complete as might be wished, owing to the non-completion of the survey of the district. The granitoid gneiss occupying the greater part of the gneissic area offers nothing but building stone ; but of this much is of great beauty and value, and has been very largely used for many large native buildings, as the forts at Vellore and elsewhere, and among European buildings, particularly in the construction of many railway stations, bridges, and culverts.

The highly felspathic varieties of the granite gneiss are occasionally so greatly decomposed as to appear to offer sources for the collection
 Kaolin. of kaolin or China clay. When carrying on the survey of the Vellore and Eudialtham taluqs, I noticed various spots which appeared to me to be deserving of attention with this object till I had seen some of the great China clay works in Cornwall, which I visited specially for the purpose of study when at home in 1868.

The conclusion I then came to was, that none of the North Arcot localities showed rocks sufficiently rich in decomposed felspar to be of much importance. The extent to which the Indian rocks have been penetrated by decomposition is greatly less than the Cornish rocks, and the quantity of clay which would therefore be procurable in India would, area for area, be greatly smaller than in Cornwall. Added to this very serious disadvantage is the difficulty of a suitable water-supply. To insure the preparation of kaolin of good color, which alone commands a high price, a very large supply of perfectly limpid water is a *sine-qua-non*. This is not always easy to obtain even in a rainy climate like that of the south-west of England, where running streams are of frequent occurrence, and in a dry climate like that of the Carnatic, this want could only be met by the construction of special reservoirs of large size, in which the water could be allowed to stand for many months after the rainy season, till all the suspended particles of ferruginous clay had settled, and the water itself has become perfectly limpid. If the great cost of providing such supplies of limpid water free from saline matter in an eminently dry country be taken into consideration, together with the fact that the kaoliniferous decomposed rock occurs in greatly smaller quantity, and is generally much less free from ferruginous staining due to the filtration through the almost universally overlying red soil, the conclusion seems inevitable that the prospects of establishing profitable China clay works in North Arcot are not very promising.

To return to the subject of building stones : the rocks of the gneissic series
 Building stones. alone offer an inexhaustible supply, and localities which would yield first rate material in any quantity might be enumerated by the score, if needful. The mention of only a few must, however, suffice ; these are Palikonda hill, Vellore, Wandiwash, and Chitpat, south of the Pálár, and Ranipet, Sholinghur, and Trittani, north of that river.

The quartzites of the Kadapa series are too hard and expensive in working to

be used except as rough building stones; and the sandstones of the Rajmahal beds are not hard enough, except in a very few cases, to be of much value. Neither Mr. Oldham, Mr. King, nor myself came across any that were fit for first class purposes, such as millstones or grindstones. Nor were any of the clay beds noted in the Alikur and Pyanur areas of sufficiently good color to be of much value. The pottery clays used by the people are taken from the younger lateritic or alluvial deposits, and are, as a rule, of very inferior quality.

ON THE CONTINUATION OF THE ROAD SECTION FROM MURREE TO ABBOTTABAD,
by A. B. WYNNE, F.G.S., *Geological Survey of India.*

In a former paper (Vol. VII, p. 64), I described the section from Murree to Kalabagh Post, along the upper or military road through the *galis* ("gullies"), as it is usually called.

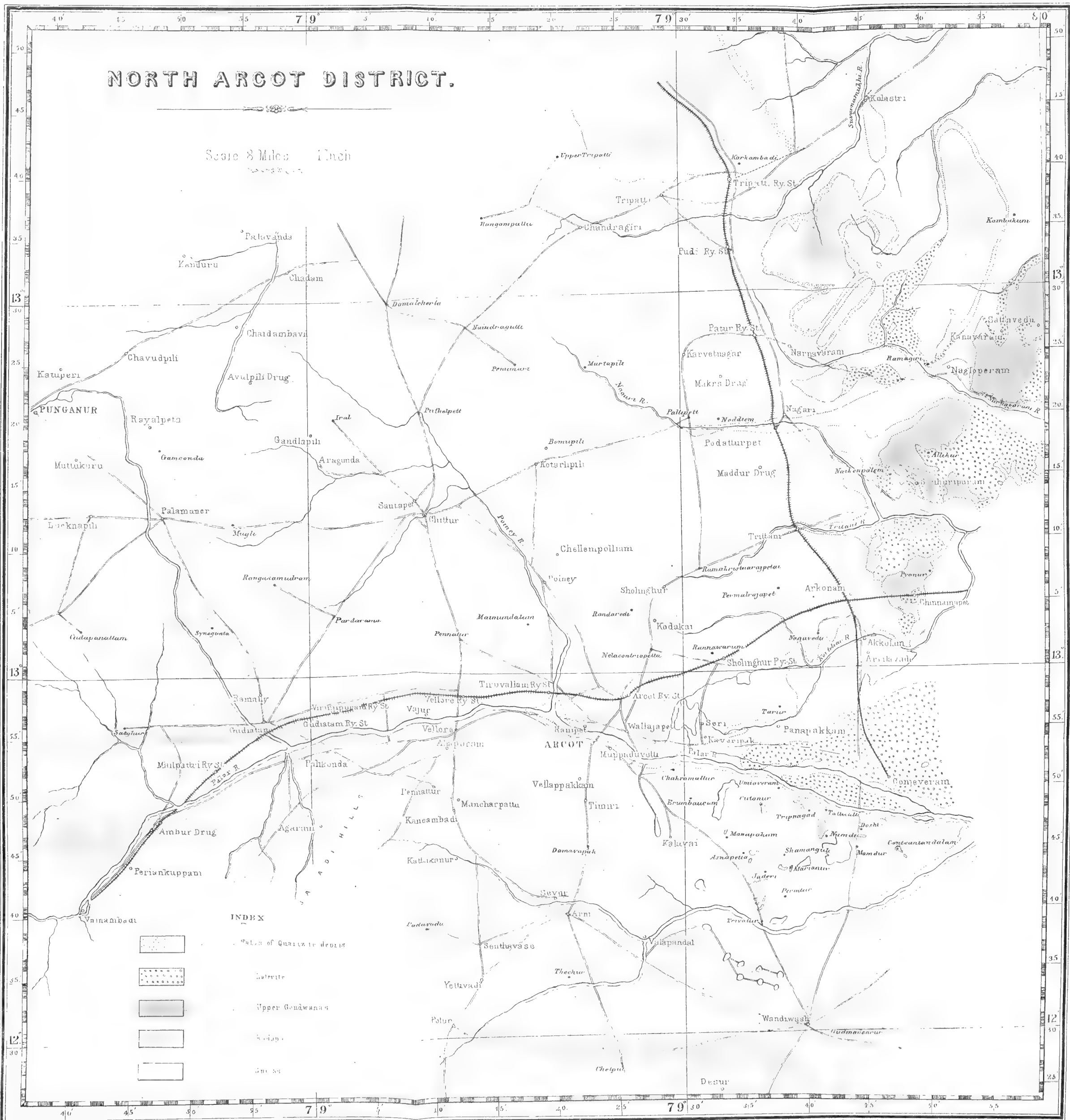
At Kalabagh, the summit level of this road (about 8,000 feet by aneroid), the nummulitic limestone and shales of the hills are in junction with the azoic Attock slates of the Mian-jani-ka Chowki range, this junction being apparently effected by means of a fault concealing all of the intervening rocks that may be present. The slates are much folded and, about half way between Kalabagh and Baragali, include a band of the usual frilled, dolomitized, seemingly slightly altered and entirely unfossiliferous limestone found elsewhere in these slates. It extends in the strike across the ridge supporting the road, and similar bands may be seen projecting at the surface of a spur from Mianjani mountain, and forming the crest of another ridge running out westward from Baragali, in both cases with a northerly dip. Near the last-named place the slates contain bands of hard dark grey or bluish silicious sandstones, and further on down the steep incline to the northwards at Bantangi purplish-red slab-slates occur near the junction with the limestones of the northern side of the great Mianjani slate tract.

The junction here differs from that at Kalabagh, but has scarcely less the appearance of a faulted or dislocated contact, the plane of which is partly vertical and partly sloping to the north, for on the western side of the Batungi Kad, the limestone, almost entirely concealed by dense forest, slopes upward and backward to the south, while the whole hill face on the opposite side of the Kad is of slate, as usual crushed, contorted, and folded.

Just at the contact, where a purplish color pervades the slates in some places, the next adjacent rocks are vertical light-colored quartzites, of small thickness, succeeded by compact and sandy limestones containing many impressions and sections of brachiopods, mostly of small size, many of them resembling casts of *Terebratula*; some obscure spiral gastropods, and some layers crowded with the curved fragments of small bivalves also occur. These hard limestones have nothing beyond the most general similarity to the hill nummulitic limestone beds; they are often dark or nearly black, and some of the bluer layers present a curious but characteristic yellow-mottled appearance frequently observed in the limestones of the Dungagali and Changlagali road, where these

NORTH ARCOT DISTRICT.

Scale 8 Miles 1 Inch





have been supposed of triassic age, for which, however, there seems little more than a conjecture on the part of Dr. Waagen, as the fossils, when the beds contain any, are mostly very obscure. Other beds show a tangled mass of fucoids on the surfaces. These limestones are largely distorted, forming at first a complex synclinal curve crossed by the throat of the Batungi gorge. Before leaving this narrow part of the gorge and turning eastwards towards Bagnotur, the road crosses a small hollow in the limestone hills north of the synclinal arrangement of the beds. In the hollow and on the slopes on the opposite side of the Kad some small *dogas* or field terraces show the waste of dark shaly rocks, so that possibly some fragment of Spiti shales may here occur, to mark a boundary. Beyond this hollow and until the road has curved eastward, the dark limestones become more like the lowest of the nummulitic ones; they contain disseminated and nodular pyrites and a thin band or bands of very dark coloured ferruginous clay with rounded quartz grains and spangles of mica, but no fossils could be detected. Just at the turn some broken and detached portions of what may once have been a more continuous layer of dark ferruginous oolitic hematite clay is enclosed among the limestone beds. It has slight resemblances to the golden oolite of the Salt-range and Kach, but is not identical with that rock. A little way beyond it the limestone, if it has any general dip, slopes southerly, and the first distinct traces of nummulitic fossils appear in foraminiferous forms distinguishable with a good lens, amongst them the little organisms referred to in a former paper (Vol. X, p. 114), and tiny *Rotulina*-like forms, as well as little nummulites, most of which might escape observation with unassisted eyes.

At Bagnotur one has descended some 3,230 feet (aneroid) from Kalabagh, within a distance of five miles by the road (much less in a straight line), and just before reaching the bungalow or rest-house, the Attock slates again appear, occupying, beneath enormous masses of debris, the lower part of this valley and that of the river Dore coming from the eastward, which here unite. The slates continue in this position, chiefly on the south side of the Dore valley, uniting eastward with the main mass of the Mianjani exposure, so that the limestones just now mentioned form a tongue stretching in the direction stated from those occupying much of the northerly parts of the lower Hazara hills. As it is the nummulitic part of these limestones which occurs in junction with the slates and not one of the older groups, it may be presumed the contact here again is effected by a fault.

Following the Abbottabad road from Bagnotur downwards to the bridge over the Dore, 670 feet below the bungalow, another apparently faulted junction with the limestones is crossed before reaching the lowest point. These limestones dip north-westward, are strong-bedded, compact, and of dark-grey colour, containing small fragmentary fossils, amongst which I observed the basal portion of a shark-like fish tooth. They are sometimes semi-oolitic, and sometimes contain knots or blebs of carbonate of lime, the whole assemblage having the aspect of the supposed triassic limestone of these hills.

Where the Dore bridge spans the chasm below this point, similar limestones dip at high angles to the eastward, and rising from the bridge high over the northerly channel of the stream, they are seen to include a 10-foot band of

purple and light-coloured ferruginous shale lying between dolomitic and dark lumpy bands. Further on dirty brown limestone is full of shell fragments, and again solid limestone alternates with shaly bands.

This gorge is the most profound traversed by the road; on one of the mountains close to the westward, overlooking it, a height is marked of 6,645 feet; and supposing the stream to be 4,200 feet, the section exposed in the steep mountain side may be nearly 2,000 feet in height. The rocks for about a mile in the narrow part of this gorge are all of the triassic aspect just now described, and they are seen to be contorted in the wildest fashion, a group of hard beds showing their edges vertically for some hundreds of feet, and standing as it were upon a strong horizontal outcrop below, as well as presenting in other places a variety of compressed curves. Leaving the narrow part of the gorge and descending into the valley of a small tributary from the east, the Attock slates are again exposed, forming a small denuded inlier, beyond which northwards crags of the disturbed triassic-looking limestone reappear. Just beyond this, the Dore river bends to the west, and in its further bank (the left), there is an exposure of black Spiti shale with fragmentary *Ammonites* and many *Belemnites* as usual. From this onwards, the road rises high above the right bank of the river, and passes along cuttings in much contorted nummulitic limestone, with two or three exposures of black coaly or carbonaceous shale, associated with ferruginous and quartzite sandstone. Black shales are also seen cropping out at the lower part of the limestone cliffs on the opposite (southern) side of the river.

As the valley opens and the road enters the little flat of Damtour, limestones of triassic aspect come out from under the nummulitic ones, and form the face of the hill east of the village. Beneath these limestones are seen the Attock slates with a high easterly dip, and the lowest bed of the limestone series above, resting directly upon the slates, is a sandy conglomeratic one enclosing fragments of the underlying slate group, as observed in the Sirban mountain sections; but it is worth notice that the largely developed masses of red sandy or earthy ferruginous beds and greyer silicious dolomites representing the *Infra-trias* group of that adjacent mountain are here absent.

From Damtour onwards the road passes among and over the deep detrital deposits of the Abbottabad plain.

The mountains to the eastward repeat, with numerous disturbances and dislocations, the features of the Sirban mountain section, described in *Memoirs Geological Survey*, Vol. IX, Art. 3. The Spiti shales are locally more largely developed, and likewise fossiliferous *Belemnite* and *Ammonite*-bearing sandstones, which may be a portion of those referred to the *Gieumal* group. The *Infra-trias* cherty dolomites are largely present in the northern parts of these mountains, but appear to be capriciously distributed, sometimes alternating with sub-fossiliferous bands having entirely the triassic aspect, and in places occurring in some force before they rather suddenly disappear to the southwards. Their connexion with the Tanol group of Hazara is strongly suggested by the sections in the northern parts of these hills, and will be referred to in a separate note.

DONATIONS TO THE MUSEUM.

1ST JULY TO 30TH SEPTEMBER 1879.

*Donors.*Coal-shale with *Vertebraria*, from Wallerawang, New South Wales.Coal-shale with *Glossopteris*, same locality.

(Through V. Ball, Esq.).

PROFESSOR BOYD DAWKINS.

Eight specimens of minerals and rocks (all metamorphic) from above 8,000 feet on the Safed Koh, near Gandamak.

MAJOR H. C. B. TANNER.

White quartzite, highest peak of the Safed Koh.

White marble from Safed Sang.

Soapstone, Terakai hill summit, above Murkekkel.

G. B. SCOTT, Esq.

A collection of rock fragments and pebbles, many rolled and imperfect fossils, and small samples of soil from between the Khojah Pass and Sugari Barkhan. (See Pro. Asiatic Society, Bengal, June 1879.)

LIEUTENANT R. C. TEMPLE.

Geological specimens, mostly small rock-fragments and some fossils, cretaceous and tertiary, from Southern Afghanistan. (See Pro. Asiatic Society, Bengal, August 1879.)

SURGEON-MAJOR C. F. OLDHAM.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1879.

*Titles of Books.**Donors.*BIGSBY, J. J.—*Thesaurus Devonico-Carboniferus. The Flora and Fauna of the Devonian and Carboniferous Periods* (1878), 4to, London.BOYD, R. NELSON.—*Coal Mines Inspection, its history and results* (1879), 8vo, London.DOYLE, P.—*Tin Mining in Larut* (1879), 8vo, London.

THE AUTHOR.

HAECKEL, ERNST.—*The History of Creation, Vols. I-II* (1876), 8vo, London.HARRISON, W. JEROME.—*Practical Geology* (1878), 8vo, London.HARTIG, DR. THEODOR.—*Anatomie und Physiologie der Holzpflanzen* (1878), 8vo, Berlin.HUGHES, A. W.—*A Gazetteer of the Province of Sindh* (1874), 8vo, London.

W. T. BLANFORD, Esq.

*Titles of Books.**Donors.*

LINDLEY, DR., AND HUTTON, W.—*Illustrations of Fossil Plants* (1877), 8vo, London.

McCoy, F.—*Prodromus of the Palæontology of Victoria, Decade IV* (1876), 8vo, Melbourne.

MORRIS, JOHN.—*A Catalogue of British Fossils, 2nd Edition* (1854), 8vo London,

F. FEDDEN, Esq.

OWEN, RICHARD.—*Memoirs on the Extinct Wingless Birds of New Zealand, Vols. I and II* (1879), 4to, London.

Royal Society's *Catalogue of Scientific Papers, Vol. VIII* (1879), 4to, London.

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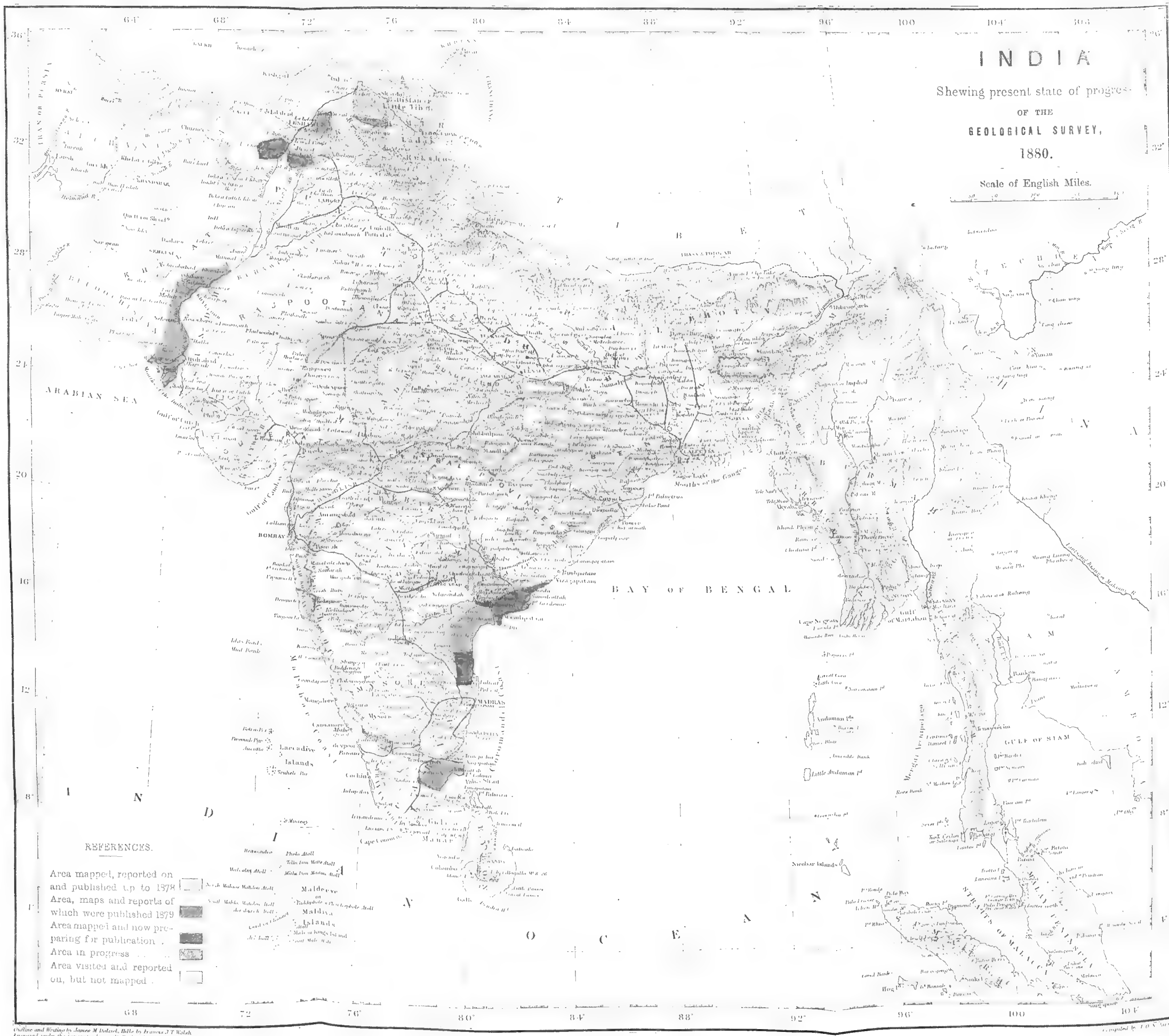
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RECORDS

OF THE

GEOLOGICAL SURVEY OF INDIA.

Part 1.]

1880.

[February.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1879.

In the *Peninsular area* there were five survey parties at work during the field season of 1878-79.

As announced in the annual report for 1878, Mr. Foote took up new ground
S. INDIA: to the south of Trichinopoly, to trace out in that direction
Mr. Foote. any remnants of the deposits of various ages already
known along the coastal region to the north. He carried his work through the
Pudukotai State to the latitude of Madura, but nothing of interest was found.
The irregular boundary of the gneiss occurs at a distance of about 35 miles from
the coast, and the intervening ground is principally occupied by the lateritic
formation, overlying and closely connected with the Cuddalore-sandstone group,
first described by Mr. H. F. Blanford in the Trichinopoly area. Its exact age is
still undetermined—probably older tertiary. The laterite overlaps it to the west,
and rests on the gneiss. Mr. Foote's account of this ground is published in the
August number of the Records.

Mr. Foote's map and description of the North Arcot district, published in the
Records for November, were compiled from observations made many years ago
by himself and other members of the Survey.

In the Pranhita-Godavari area, besides the general extension of his survey of
GODAVARI: all the Gondwána rocks of that basin, Mr. King has fairly
Mr. King. succeeded in maintaining a distinction of upper and lower
in the Kota-Maleri series, so far as established by overlap, which is still the prin-
cipal feature of unconformity between the several groups of the Gondwána
system. Within the local basin we are indeed still unable, as was shown by
Mr. Hughes (Records, XI, page 29), to demarcate the groups closely, but Mr.
King has found that to the south there are no representatives of the Maleri clays
between the Kota beds and the Sironcha sandstone, which he now recognises as
belonging to the Kámthiis (lower Gondwánas). The conjectured intercalation of
the peculiar fossils of the two zones has not been confirmed, so as to modify this
stratigraphical indication; and thus the original distinction indicated by the
liassic fossils of the Kota beds and the rhæto-triassic fossils of the Maleri clays
stands for the present confirmed. (See Pal. Ind., Ser. IV, 2; Manual, p. 151.)

In continuation westwards of Mr. Ball's survey of the Aurunga and Hutár SON BASIN: coal-fields (Memoirs, XV, Pt. 1), Mr. Griesbach, during *Mr. Griesbach.* last field season, mapped and described some 900 square miles of Gondwána rocks in Ramkola, between Tatapáni and the Rer river (his Memoir is now at press, as Part II of Vol. XV). This ground is the easternmost prolongation of the great central area of South Rewah or the Son, extending westwards to near Katni on the Jabalpur railway, and south-eastwards into the Mahanadi basin, to near Sambalpur.

In the report for last year I gave a brief discussion, based upon Mr. Ball's description, of the stratigraphical features of this region as the transition ground between the well-marked divisions of the lower Gondwána series in the Damuda valley and the conditions found in the midland areas, where the higher groups of the lower Gondwánas, as in the Kámthi and Hingir beds, exhibit more the petrological characters of the upper part of the series. It seemed as if in the Hutár field and locally in the Aurunga field, we already had this condition established; and I pointed out that we only awaited the discovery of lower Gondwána fossils in the overlying sandstone here to make certain of it, and hence to draw some important inferences regarding the horizon of the top sandstone ("upper Panchet") of the Damuda fields. It seems, however, that we shall have to look farther west, within the midland area itself, for the facts of this stratigraphical change. Mr. Griesbach has traced a Raniganj group, with good fossil characters, and a Panchet group less distinctly, at and west of Tatapáni; but these have been reclaimed chiefly from the low-lying outcrops previously supposed to be all of the Barakar group,—not from the hill-forming sandstone, from which the upper (? Panchet) beds are not easily separable. Mr. Ball gave in his map of the Hutár field an indication of the possible position of an intermediate group.

A principal object in sending Mr. Griesbach at once to a typical Gondwána area was, as mentioned in last annual report, that he might elucidate the supposed similarity between these rocks and the Karoo formation of South Africa; indeed this object was of much weight in recommending his appointment to the Survey. In this respect his memoir on the Ramkola coal-fields will be found disappointing, the more so as it shows him to have considerable proficiency in the art of geological surveying. Mr. Griesbach has reserved his observations on this point for a still wider comparison in connection with his more recent work in the Himalayas, of which a notice will be given in the Records for May. He has verbally stated that the Talchir boulder bed bears a very strong resemblance to the Ecca beds of Natal, and his descriptions exhibit more strongly than any yet given some of the glacial characters of the boulder bed; but he refrains from any expression of opinion on this much-vexed question.

It will be seen that the map of the Ramkola fields exhibits a free use of faults, therein resembling other maps of similar ground. The practice is quite legitimate, faults being a very common feature in such rocks; but it is capable of abuse, and it has often seemed to me that this limit has been passed in our descriptions of these Gondwána basins. A main boundary is represented as a fault, without a word to qualify all the inferences that would follow from the simple use of that word. Thus, as to the throw of this fault, that it amounts at least to the

total thickness of the strata on the downthrow side. No *á priori* objection could, indeed, be made on this count, for faults of very great throw are fully established; it is the discrepancy of the fact with other features of the description that calls attention. Thus, immediately on the upthrow side of such a fault, or near it, patches of the highest beds of the downthrow series may be seen resting on the base-rock, which fact at once makes the fault in its *primâ facie* aspect impossible. When attention is called to this, the usual explanation is, that the fault occurred before that upper group was deposited. This assertion is not so easily disposed of, but I consider that in the cases before us it is in a great measure disposed of: it may, I think, be held as impossible that disturbance of such magnitude as is implied by a fault of several thousand feet throw could take place between two groups of a stratified series, and not produce far greater effects of discordance than have as yet been observed between any groups of the Gondwána series. I do not forget that I have myself illustrated the compatibility of complete apparent conformity with synchronous great disturbance in the immediate vicinity (Manual, pp. 550-551); but that case rather enforces than invalidates the remarks I have just made: if the apparent discrepancy to which I have called attention were susceptible of an analogous interpretation, the notice of the feature as a simple fault would be none the less misleading. I would again invite my colleagues to a more critical attention to their 'faults': an erroneous fault within the stratified series may only lead to mistakes in calculating the position of any particular bed; but a mistake as to the nature of a main boundary leads us altogether astray in judging of the original conditions of the formation, the discovery of which is a principal object of our study. Thus, for this Gondwána formation, it is generally supposed to be in the main of subaerial origin, by rain and rivers, and presumably accumulated upon an area of subaerial erosion; yet the ever ready introduction of faults, pure and simple, at the limits of the basins, leaves this supposition out of sight.

In Kattywar, which belongs to the peninsular area, on the southern confines of the Arvali metamorphic region, Mr. Fedden completed the survey of some 1,900 square miles (sheets 24, 25, and 36) in continuation to the south of his previous season's work, besides making some preliminary traverses of adjoining ground. With the exception of a small inlier of Upper Gondwána (jurassic) rocks of the Umia horizon near Mewása, and very local outcrops of a sandstone locally underlying the trap, but containing trappean débris, the whole area is occupied by the great eruptive formation. It is mostly stratified, having a slight inclination to the south, but huge dykes traverse it in various directions, forming prominent ridges across the low undulating country. Terraces of the marine miliolitic limestone occur locally halfway up the sides of these ridges. The marble of local repute as Gondal marble is only an irregular sparry vein in the trap, not more than 2½ feet wide; it occurs at Khirsára and Sajriáli, 15 miles north-west of Dhoráji. A cursory visit was made to the famous Junagarh hills, the volcano-like construction of which was early noticed, but which were said to be in part formed of gneissic or granitic rocks. The isolated central hill forming the sacred peak of Gírnár is a mass of thoroughly crystalline rock, a granular compound of a clear plagioclase

felspar and a dark-green mineral principally, if not all, biotite, and it seems, indeed, to be the core of a volcanic focus. The annular ridge surrounding Gírnár, outside a deep intervening valley, is largely made up of trachytic dykes and bedded basaltic masses with a quaquaversal slope.

In Rajputana Mr. Hacket added a very large area (more than 10,000 square miles) to his previous survey of the Arvali region, extending to the south-west as far as Erinpura. The scattered position of the outcrops in a wide-spread waste of sand makes such a result possible. As soon as the area to the east of the range is filled in, up to the Vindhyan scarp near Búndi, as Mr. Hacket hopes to accomplish during the present field season, a connected account of this portion of the region, up to Delhi, can be published.

The Vindhyan strata were found to cover a large area to north and east of Jodhpur. Their most north-easterly outcrop is at Khátu, 80 miles north-by-east from Sojat. They everywhere rest flatly upon the old rocks—the gneiss, the Raíálo schists, the Maláni felsites, or the Alwar quartzites. There is generally a thin band of fine quartz conglomerate, or of green shales, quite unaltered, at the base, overlaid by pale fine sandstone like the Kaimur rock, to which succeeds a red rock like the Bhánrer sandstone. The whole varies in thickness from 100 feet at Sojat to 350 feet at Klátu. There is sometimes a conglomerate between the two types of sandstone. Cherty calcareous beds are associated with the red sandstone at top, thus connecting this rock with an overlying limestone that covers large areas; it is locally 200 feet in thickness.

A very peculiar boulder formation is described as occurring on and about the Vindhyan, especially the limestone, yet not belonging to them. The blocks, up to 3 feet in diameter, are thoroughly water-worn, formed exclusively, so far as observed, of the Álwar quartzites. They lie loosely, without any matrix, in banks sometimes more than 100 feet thick.

The felsitic eruptive rocks described by Mr. Blanford as the Maláni beds, south of Jodhpur, are considered by Mr. Hacket to belong to the Raíálo horizon, as he found typical beds of that rock associated with the schists north of Dewair, in the centre of the Arvali range.

In the *Extra-Peninsular area* there were two survey parties at work in the cold season of 1878-79; and in the summer of 1879 two were engaged in the high Himalayas.

With the new maps of Kumaun Mr. Theobald surveyed, or at least explored, SUB-HIMALAYA: the belt of tertiary rocks at the base of the mountains between the Ganges and the Káli, in continuation of the work done several years previously to the west of the Ganges. Since these lower hills have been so extensively taken up for forest reserves they have become more inaccessible than ever, the temporary villages and the paths connected with them having disappeared.

The Siwaliks of this region (if indeed the strata of these flanking ridges include true Siwaliks, as Mr. Theobald seems to think) still maintain their character as unfossiliferous, no success having rewarded the search of so

experienced a collector. Other results, too, are wanting; the so far unique occurrence of eruptive rock in the tertiary sandstones at the Gola river (*see* Manual, p. 543) remains undescribed. After several consecutive seasons' work upon these sub-Himalayan rocks, Mr. Theobald has now seen more of them than any one else, and he should be in a position to throw some light upon their structure and history. There is no lack of independent speculation in the several progress reports sent in, but there is a too conspicuous want of critical observation, whether in support of the several conflicting views put forward by himself at different times, or in refutation of the interpretations already published by others. After the present season's work, however, we must place on record the result of his more matured study.

In the past field season, or in part of it,—for he also made a reconnaissance of

SALT-RANGE: the ground far to the north between Kohat and Thal, on
Mr. Wynne. the Kuram,—Mr. Wynne accomplished the survey of the

western extension of the Salt-range, from the Indus to the outskirts of the Sulimán range, beyond Shekh Budin. Following the great curves of the range, its length is about 100 miles, and considering the great intricacies of the sections, and the peculiar interest of many features of the ground, it will be readily understood that so rapid a survey cannot be very searching, much less exhaustive; but Mr. Wynne's map and description will form a thorough guide to future explorers, the leading features being no doubt portrayed with sufficient accuracy. Although the rock-salt, which gives its name to the Salt-range, extends a very short way west of the Indus, all the main structural characters of the western extension correspond with those of the cis-Indus Salt-range, with which Mr. Wynne is so familiar; indeed, without this knowledge the work could not have been accomplished. A principal variation found in this new ground is the expansion of the boulder zone, which near the Indus is the only rock between the Productus-limestone and the Salt-marl. At the south-west end of the Khasor ridge the purple sandstone is again in force, but with an intervening band of red clays, gypsum and dolomite, which alternate with the boulder beds at top. These middle beds are unlike those of similar composition in the saline series, below the purple sandstone, although their general composition would seem to connect them with those lower deposits of the Salt-range series. Mr. Wynne, however, suggests that they may represent the *Obolus* beds, which in the east Salt-range rest on the purple sandstone. Although nearly suppressed in the Maidán-Chicháli part of the range, the Ceratite and Productus-limestone groups are again exposed in force in the Khasor ridge, with very much the same characters as in the western portion of the Salt-range proper.

The jurassic series becomes more developed to the west of the Indus, and a well-defined distinction takes place between an upper calcareous marine zone and a lower one of sandy argillaceous deposits with plant-remains. Mr. Wynne calls attention to the contrast presented in this respect by the jurassic series here and in Rajputana, where the terrestrial (*Gondwana*) characters occur in the lower division, below the marine limestones, and the series as seen in Cutch, where these characters are found in the upper beds (the *Umia* zone) above the purely marine deposits.

A cretaceous zone seems to be the least defined of any in the trans-Indus series: while the original representative of a neocomian band is described as inseparable from the jurassic deposits, an overlying sandstone of the Chicháli section, at first conjectured to be possibly cretaceous, is described as apparently representative of a rock elsewhere shown to be post-eocene. The treatment of this horizon of the sections, the base of the tertiary series, is perhaps the least conclusive part of Mr. Wynne's work. Altogether his memoir will in this respect prove highly suggestive to future explorers.

By his trip through the very unfrequented ground between Kohát and Thal, of which an account is published in the Records for the year, Mr. Wynne was able to complete an unfinished border of the map and description previously given (Records, 1877) of a large area of the north-west Punjab.

In the introductory sketch to his description of the Salt-range fossils, in the *SALT RANGE: Palæontologia Indica*, Ser. XIII, fasc. 1, Dr. Waagen *Dr. Waagen.* proposes a very important change in the grouping of the lower deposits of that area. Since the discovery of an *Obolus*, by Mr. Wynne, in one of the local groups of the series, represented as separated from the overlying Productus-limestone by two intervening groups in which no fossils had been found, although all do not occur together in any one section, it had been received as probable or possible that the Salt-range might contain a more or less partial representation of the palæozoic series, between the silurian, as represented by the *Obolus* beds, and the carboniferous represented by the Productus-limestone. Dr. Waagen now proposes to place all the four groups in one connected series, which he calls the Productus-limestone series. Such an arrangement would, of course, be impossible under any literal sense of the terms silurian and carboniferous, as previously applied to the separate groups. It is easy to imagine how the *Obolus* may be disposed of; Dr. Waagen's description of the fossils has not yet got so far; but he has not failed to indicate (*l. c.*, pp. 7 and 8) that he considers the deposits to be in succession laterally transitional and vertically associated so as to be inseparable.

Dr. Waagen has contributed to the November number of the Records an interesting suggestion regarding the older rocks of the Hazára region. It is based upon some fossils sent to him by the Geological Society of London for description in connexion with the Salt-range fossils. Among them were some in a black slate; they were labelled 'Punjab'; and there is some presumption that they may have come from the Attock slate group, which has as yet yielded no fossils to our search, but which has been provisionally ranked as silurian, partly from an equally uncertain conjecture (*see* Manual, p. 500, note) regarding some fossils found beyond Pesháwar. Dr. Waagen's fossils are of a well marked carboniferous type, and he points out that this age for the Attock slates would at least help to clear up some very puzzling features in the geology of Hazára.

Mr. Lydekker explored a large area of Ladák to the east of his previous observations, and several points of interest have been determined. The gneiss of the Ladák axis, or Kailas range as Mr. Lydekker now calls it (in the Manual local names were preferred until we should know more about what we were discussing), was understood from Dr.

Stoliczka's description to be chiefly, if not altogether, formed of altered palaeozoic rocks. Mr. Lydekker now shows that the gneissic silurians only occur locally, and that the principal mass must correspond to the 'central' gneiss (or Cambrian gneiss of Mr. Lydekker's previous papers, the identity of which with the 'central' gneiss may perhaps be doubted). The conformity and transition from one to the other is everywhere apparent. The metamorphics of Rupshu are, however, all represented as converted silurians. Thus we should still have to find the gneiss that yielded the blocks in the silurian slates of Pángi, and to explain the sharp unconformity of upper silurian strata on granite and gneiss in Hangrang. (Records, XII, 61.)

A special interest has been noted (Manual, p. 643) as attaching to the great trough of tertiary rocks found along the course of the Indus at the southern base of the gneissic range in Ladák, and crossing obliquely, with the great river, to the north side of this gneiss at a point south of the Pangur lake. Mr. Lydekker now shows from good sections that at several points of the boundaries, both with the oldest gneiss on the north and with the carboniferous rocks on the south, the natural original junction is exposed; and this is quite enough to rule the case, though at other points slipping may have been superadded. In several instances the bottom conglomerates of this eocene formation were even observed to show a relation of distribution with reference to the actual gorges of the gneissic range. We may thus henceforth dismiss from our speculations any thought of a former direct connexion of these central Himalayan eocenes with those at the base of the mountains in India, although the similarity of the deposits is so striking. Supposing that the formations of the Zánkár and Kárákoram basins were once continuous across the position of the Ladák axis, it would thus also be proven that a pre-eocene Himalayan elevation took place equal at least to the total thickness of the present sedimentary series from the base of the old gneiss to the top of the cretaceous; for only the unaltered portion of that series this would amount to 16,000 feet, according to Stoliczka's estimate. What the actual elevation of the mountains adjoining the eocene gulph may have been would, of course, depend on how far erosion had kept pace with elevation. The time required for such an erosion must be very great.

Upon the very interesting question of the amount of contortion that accompanied that great pre-eocene elevation, Mr. Lydekker seems to be slightly at variance with his facts, or at least his particular facts, as he duly observes, do not support the opinion he bases upon more general observation. He considers that the contortion of the older rocks took place in great part before that of the tertiaries, because the former exhibit puckerings and crumplings not found in the latter; but in the only contact section given that is not one of original abutting deposition, in the inlier at Miru, the carboniferous and eocene strata are nearly vertical in parallel superposition, so the older must have been flat at the time of deposition of the newer. It is certain that much compression and some crumpling must have attended the depression of the great sedimentary series, when its lower members were converted into gneiss; but it seems to me still an open question whether the great contortions which we now look upon as the special Himalayan disturbance, may not be post-eocene, though, of course, their

lines were determined by the great preceding act of general elevation. (*See Manual*, p. 634.)

Mr. Lydekker observes that the extensive exhibition of irruptive rocks connected with the tertiary series is not continuous throughout, and that the masses to the east are different in composition, or at least in texture, from those at the north-western end of the basin. This latter fact may be due to metamorphism accompanying the greater compression in this position, and which has equally affected the tertiary deposits.

Mr. Griesbach has accomplished a very successful season's work in the higher

NITI: Himalaya of Kumaun and Hundes. Compared to Ladák

Mr. Griesbach. this is a happy hunting ground for the geologist, the rocks being well stocked with fossils, of which a good series has been brought in. Despite the distress of climate and great elevations, Mr. Griesbach has succeeded in mapping the snowy range between the Niti and Milam passes. He is still engaged in working up his materials, and the result cannot fail to be most interesting.

Mr. Blanford was engaged at office during the whole field season, at first for the completion of the *Manual* and afterwards to prepare his memoir on Western Sind, which had been postponed for some time.

Nothing special occurred to take me from Calcutta, and unless for some urgent duty of short duration, my absence would not be compatible with the steady progress of our work.

Publications.—Mr. Wynne's geology of the Salt-range was at last issued early in the year, having lain some fourteen months in type waiting for the colour-printing of the map. It forms itself Vol. XIV of the *Memoirs*. Mr. Foote's memoir (Vol. XVI, pt. I.) on the geology of the eastern coast from latitude 15° to the Kistna was issued in August. Mr. Blanford's geology of Western Sind was issued in December, forming Vol. XVII, pt. I, of the *Memoirs*. When the work admits of it, memoirs on adjoining areas, or relating to the same geological region, are brought into the same volume; thus, Vol. XV will be completed by Mr. Griesbach's memoir on the Ramkola coal-fields, now in the press: Vol. XVI will include Mr. King's memoirs on the east coast in Nellore and in the Godavari district, now preparing for publication; and Vol. XVII will be completed by Mr. Wynne's geology of the Salt-range trans-Indus, now at press.

The *Records* for 1879 contains 22 papers of various interest, with 11 maps and plates. Two of the articles are by contributors not attached to the Survey: that on Hangrang and Spiti by Colonel McMahon, and that on the old mines at Joga on the Narbada by Mr. G. T. Nicholls of the Civil Service.

Four parts of the *Palæontologia Indica* were issued during 1879: one by Dr. Feistmantel on the Flora of the Gondwana outliers on the Madras Coast (16 plates), and another by the same author on the Flora of the Talchir-Karharbari beds (27 plates); one by Mr. Lydekker on the Reptilia and Batrachia of the Indian pretertiary formations (6 plates); and the first part of the Salt-range fossils by Dr. Waagen (6 plates). An interruption was occasioned in the publication of Dr. Waagen's work by his receiving in the middle of the year the considerable collection of fossils made in the preceding field-season by Mr. Wynne in

the trans-Indus Salt-range. These had to be cleaned out and arranged with the previous collections before the work of description could proceed. I have already received plates and text in continuation of the work, including some of the specimens sent during the year.

I have great satisfaction in announcing that the description of the Sind fossil corals so generously undertaken for the *Palæontologia Indica* by Professor Martin Duncan, F.R.S., is very nearly completed. This is the fourth instance of distinguished palæontologists in England giving valuable assistance to the Geological Survey of India by the description of important groups of fossils.

I took an early opportunity, in the annual report for 1877 (*Records*, Vol. XI, p. 12, 1878), to state the principle of liberty and distributed responsibility under which I proposed to conduct the publications of the Geological Survey, and to explain how the conditions of our work in this country—the great distances to be accounted for and the peculiar difficulties of locomotion—made some such rule necessary to the full performance of our duties to the public. The evident drawback to such practice is the publication of crude work, in which even the competent reader (without any knowledge of the ground) can perceive that more intelligent observation might have given a very different account of the sections. To obviate this objection, the only alternative would be to withhold work from publication until it could be revised in the field by a more thorough observer. Unfortunately, owing to the great scarcity of really accomplished observers, and under the circumstances already noted, this would mean a quite indefinite postponement, and a stoppage of other work. Such had formerly been the practice: in view of further corrections the description of the Rájmahál hills had been withheld for fifteen years, and is at last in quite an unimportant degree better than it would have been at the first; and this is by no means an isolated case. Now, our principal duty is to the greater public, to furnish an intelligible map and description of areas hitherto geologically blank; and our least finished work does that, however imperfectly. The claim of the very select public of competent geologists—that all our work should be up to the best standard of the day—is incompatible with that prior claim, and with the conditions of the situation, subjective, and objective. The points where we fail in this respect do not much affect the value of the work as a guide to the ground. Of course every advice and suggestion is given in each case, so far as can be made from careful perusal of the work in manuscript, but the least intelligent workman is often the last to take advice, and the compelling reasons are mostly such as could only be worked out on the ground. I see no compromise but the one I adopted, and to which I adhere. The risk it obviously implies—the exposure of faulty work—falls upon our own heads. The minor evils it involves are no greater than those it removes, and the smart of public criticism is more wholesome than the heart-burning of official suppression. Correction is, however, seldom more convincing than advice, and in the endeavour to avoid it over-sensitive or under-ballasted writers even run into a worse predicament than that they would escape from. Thus the ball is kept up; the question of official suppression comes round again; as it is impossible that our publications can be made the vehicle of querulous rejoinders. Appeal is then made to non-official censors. Kindly editors of independent journals, quite ignorant of the merits of the case, and too busy to examine it very critically, act

upon the too plausible assumption that an eager protest against superior authority is probably well founded, and so they publish communications which their better judgment might lead them to decline, if only for the sake of the writer himself. I regret that an illustration of this difficulty has occurred during the past year.

Museum.—The various collections are in good working order. Two small popular guide books were prepared; one by Mr. Lydekker for our fine series of tertiary vertebrates, and one by Mr. Mallet for the minerals; they are sold for mere cost price at the door, and have met with some demand. Mr. Fedden is now engaged in rearranging the meteorites, amalgamating the Asiatic Society's specimens with the larger collection made by the Survey. Mr. Theobald has prepared a brief account of meteoric phenomena to be prefixed as a popular guide to the new catalogue.

Several small collections of rocks, minerals, and fossils have been forwarded to local Museums and Colleges.

Library.—The number of volumes and parts of volumes registered as received during 1879 was 1,283; being 604 by presentation, and 679 by purchase. Arrangements are in progress for the printing of the catalogue.

Personnel.—Mr. Ball was absent on furlough for the whole year. Mr. Foote left for two years' furlough on the 13th May. Mr. Mallet took 15 months' leave, on medical certificate, on 25th July. Mr. Blanford took 15 months' furlough from 23rd August. Mr. Hughes returned from furlough on the 15th October, and has taken up work in the South Rewah Gondwana basin on the west, from Katni.

I was absent on privilege leave from 26th July to 25th October.

Mr. Richard D. Oldham was appointed by the Secretary of State as an Assistant in the Survey, and joined his post on the 17th of December. He has taken up work with Mr. King in the Godavari valley. In addition to the high proficiency in geological studies evinced by Mr. Oldham at college and afterwards by independent work, we have the pleasure to welcome him as the son of the founder of our Survey and its successful director for a period of 25 years.

Apprentices Kishen Singh and Hira Lall having served their five years of probation with sufficient credit, and having acquired a serviceable knowledge of rocks and minerals, they received, on my recommendation, permanent promotion as sub-assistants. They have been in turn usefully employed in the Office and Museum in the place of the late Assistant Curator, and this post has been in consequence dispensed with. In turns they take the field with one or other of the geologists. It is still, however, very doubtful if they can ever prove competent for independent field-work. Geologist's work may not demand high mental powers, but it inevitably requires some originality of thought in dealing with observation and induction, that peculiarly modern turn of mind to which we owe the present development of natural science, the very quality which more than any other makes the western man different from the eastern. There is little or no gradation of work in geological surveying: to observe and interpret is required from the beginning; and the observation does not consist in measurements, or any kind of manual performance, but virtually to put a life into stones, and to trace the history of that life. Unless this is done with some approach to the standard of modern knowledge the work is not worth paying for.

CALCUTTA, }
January 1880.

H. B. MEDLICOTT,
Supdt. of the Geological Survey of India.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1879.

- BATAVIA.—Batavian Society of Arts and Sciences.
 BELFAST.—Natural History and Philosophical Society.
 BERLIN.—German Geological Society.
 „ Royal Prussian Academy of Sciences.
 BOMBAY.—Bombay Branch of the Royal Asiatic Society.
 BRESLAU.—Silesian Society of Natural History.
 BRISTOL.—Naturalists' Society.
 BRUSSELS.—Geographical Society of Belgium.
 „ Geological Society of Belgium.
 „ Royal Academy of Belgium.
 CALCUTTA.—Agricultural and Horticultural Society.
 „ Asiatic Society of Bengal.
 „ Meteorological Survey.
 „ Trustees, Indian Museum.
 CAMBRIDGE, MASS.—Museum of Comparative Zoology.
 CAPE TOWN.—Ministerial Department.
 CHRISTIANA.—University of Christiania
 COPENHAGEN.—Royal Danish Academy.
 DRESDEN.—The Isis Society.
 DUBLIN.—Royal Geological Society of Ireland.
 „ Royal Irish Academy.
 EDINBURGH.—Royal Scottish Society of Arts.
 „ Royal Society.
 GENEVA.—Physical and Natural History Society.
 GLASGOW.—Glasgow University.
 LAUSANNE.—Vandois Society of Natural Science.
 LIVERPOOL.—Geological Society of Liverpool.
 „ Literary and Philosophical Society.
 LONDON.—British Museum.
 „ Geological Society.
 „ Iron and Steel Institute.
 „ Linnean Society.
 „ Museum of Practical Geology.
 „ Royal Asiatic Society.
 „ Royal Geographical Society.
 „ Royal Institution of Great Britain.
 „ Royal Society.
 „ Society of Arts.
 „ Zoological Society.
 LYONS.—Museum of Natural History.
 MADRID.—Geographical Society of Madrid
 MANCHESTER.—Geological Society.

- MELBOURNE.—Mining Department, Victoria.
 „ Royal Society of Victoria.
 MOSCOW.—Imperial Academy of Naturalists.
 MUNICH.—Royal Bavarian Academy of Sciences.
 NEUCHÂTEL.—Society of Natural Sciences.
 NEW HAVEN.—Connecticut Academy of Arts and Sciences.
 „ Editors of the American Journal of Science.
 PARIS.—Geological Society of France.
 „ Mining Department.
 PHILADELPHIA.—Academy of Natural Sciences.
 „ American Philosophical Society.
 „ Franklin Institute.
 PISA.—Society of Natural Science, Tuscany.
 ROME.—Geological Commission of Italy.
 „ Royal Academy.
 ROORKEE.—Thomason College of Civil Engineering.
 SALEM, MASS.—American Association for the Advancement of Science.
 SINGAPORE.—Straits Branch of the Royal Asiatic Society.
 STOCKHOLM.—Geological Survey of Sweden.
 ST. PETERSBURG.—Imperial Academy of Sciences.
 SYDNEY.—Royal Society of New South Wales.
 TASMANIA.—Royal Society.
 TORONTO.—Canadian Institute.
 TURIN.—Royal Academy of Sciences.
 VIENNA.—Imperial Academy of Sciences.
 „ Imperial Geological Institute.
 WASHINGTON.—Department of Agriculture, U. S. A.
 „ Department of the Interior.
 „ Smithsonian Institute.
 „ United States Geological and Geographical Survey.
 „ U. S. Geological Exploration of the 40th Parallel.
 „ Geological Survey of New Zealand.
 „ New Zealand Institute.
 YOKOHAMA.—Asiatic Society of Japan.
 „ German Naturalists' Society.

Governments of Bengal, Madras, North-West Provinces, and the Punjab; Chief Commissioners of Assam, British Burmah, Central Provinces, and Mysore; Superintendents of the Marine and Great Trigonometrical Surveys; India Office, London; Foreign, and Home, Revenue and Agriculture Departments; and the Resident, Hyderabad.

January 1880.

ADDITIONAL NOTES ON THE GEOLOGY OF THE UPPER GODAVARI BASIN IN THE NEIGHBOURHOOD OF SIRONCHA, by WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*¹

The last paper² written on the geology of this region by my colleague Mr. T. W. H. Hughes, the result, as it was, of later and more extended surveys, placed the relations of the Gondwána strata of this part of the Godavari and Pranhita area in so different a light in some respects to what I had anticipated in my paper³ of the previous year that it became necessary to revisit the ground over which I had already made a cursory tour with Mr. Hughes.

The result has been to a certain extent satisfactory: a more detailed survey of the rocks has been effected, and some clearer insight obtained of the relations of the different groups of strata; but little additional evidence has been secured as to the conditions of the horizon between the upper and lower divisions of the Gondwána system than what we have ever had in this at first very promising region for the solution of that problem. There is no doubt, however, that we have here near Sironcha two great divisions of the Gondwánas, namely, the Kámthis and an upper series which we have gradually, through Mr. Hughes' researches, come to class as the Kota-Maleris, though I was myself inclined at first to introduce an intermediate group, the Sironcha sandstones, considering it representative of my Golapilli sandstones in the lower Godavari districts.

The main question, and that on which nearly all the others hang, is, as to whether the sandstones of Sironcha town are really of the upper or lower Gondwánas; but unfortunately, after all my endeavours, I have not been able to find fossils or sections which shall absolutely settle this point, though there is plenty of negative evidence on both sides of the question. I should naturally try to employ this negative evidence in favor of my own original view of their relations, but the balance of evidence given by Mr. Hughes seems, on the whole, to be more in favor of a lower Gondwána age for these beds.

The late Superintendent (Dr. Oldham) and Mr. W. T. Blanford are, besides myself, the only members of the Survey who have examined these puzzling beds, and Blanford had already inferred that they are Kámthis. His opinion had naturally great weight with me; but knowing that he had not spent much time over that locality, and that I had already been able to eliminate the upper Gondwánas from his general area of Kámthis at Ellore in the lower Godavari district, while I had up here the remarkable section at Kaleswar, the new facies of the rocks themselves, and the find of plant remains at Anáram, I was led to surmise that there were representatives here also of the lower Godavari rocks. Hughes' paper threw considerable doubt over this suggested correlation, but his

¹ The descriptions in this paper can in great part be followed with the aid of the small map annexed to Mr. Hughes' paper in Vol. XI, Part 1, of the Records. A map of the completed survey will be published with Mr. King's full description in the Memoirs.

² Records, Vol. XI, Part 1, 1878.

³ Records, Vol. X, Part 2, 1877.

boundary between the upper and lower Gondwánas did not satisfy me. I was again extremely puzzled by fresh features in the rocks at Kaleswar, and I find that the Aravi-Somnapali sandstones underlying the Angrezpali outlier of red clays are remarkably like those of Sironcha.

However, on carefully revising my last season's work, I really see no other way to a solution of the question than to yield the point that these sandstones of Sironcha town must be of lower Gondwána age, if not upper Kámthis, then possibly an independent group.

THE SANDSTONES OF SIRONCHA.

For convenience of discussion, it will be as well to write of these still as Sironcha sandstones. I have been led in great part, over and outside of the arguments put forward by Mr. Hughes, to look on these beds as of lower Gondwána age, through having found fossils (decided by Dr. Feistmantel to be preferably of Kámthi age) in rocks of Hughes' ground on the Wardha which from their lithological characters I had at once assumed as representatives of the Sironchas. This was near Porsa, and on a horizon corresponding to that of the Aravi-Somnapali sandstones.

I have unfortunately, with all my search, not been able to find any recognizable fossils at Sironcha, though there are some fragments of stalks on red shales bearing a faint resemblance to others in the Anáram beds. It likewise appears from the following note¹ of the Rev. Mr. Hislop that fossils of lower Gondwána age were once found at Sironcha. "In the sandstone at Sironcha, 6 miles further down the river Pranhita, there is an abundance of compressed stems identical with those at Silewáda: so that there can be no doubt that the argillaceous sandstone there is of the Damuda group. This sandstone of Sironcha is stated by Mr. Wall to underlie almost immediately the Kota limestone."

Looking on the 'Sironchas' as of lower Gondwána age, I can then place the boundary between them and the Kota-Maleris more definitely than was attempted by Hughes: in fact it must run very much where I always drew the line between the Sironcha sandstones and the Maleri clays, or rather the Kotas, for the remarkable feature about the Sironcha sandstones is that they (unlike the other Kámthi or lower Gondwána outcrops to the north-west of Sironcha) are not overlaid by Maleri clays, but by Kota limestones.

From (and including) Sironcha town to the Godavari river opposite Kaleswar there is a tolerably continuous outcrop of sandstones in the left bank of the Pranhita, in which there is not a break allowing of such a boundary as that suggested by Hughes in his map being continued to the Sironcha side of the river. The Sironchas must be considered as at least extending from the north-east suburb of the town to Nagrum opposite Kaleswar. If ever it become necessary to distinguish the Sironchas as upper Kámthis or as an independent group, then their lower boundary must be drawn at Kaleswar, though not at the section on which Hughes and I ultimately agreed that there was only a resemblance of unconformity.

¹ Pro. Geol. Soc., London, 20th November 1861, Vol. XVIII, p. 36.

I have been able this year to trace decisively the beds of Sironcha town across the Pranhita into the rising ground culminating in the hill-station above Arjunguta. We had, I think, always supposed this to be the case, and the hill-station beds had ever seemed to me of a true Kámthi facies, while the ascertained continuity of strata so far carries these beds nearer to the Anáram strata with their upper Gondwána plant remains. The hill-station beds are brown and ferruginous with a decided Kámthi look, and are in part very hard and vitreous, having thus a much older appearance than the Sironchas; however, I actually found unmistakable Sironcha beds merging into these hard vitreous beds; and so there is no doubt at all, in my mind, that the Arjunguta bed and those of Sironcha are the same; while the former have the Kámthi facies. The Arjunguta hill-station is at the west-south-west end of a line of faults which may be said to limit in part the north-westerly extension of the Sironcha strata, these being also cut off to the south-east, after a length of some 15 miles, by another more or less east-and-west fault near Ardium on the left bank of the Godavari.

To the north of the Arjunguta hill-station are the oft-noted Anáram beds which yielded the plant remains *Palissya conferta* and *Chirolepis müsteri*, and which I had concluded were overlying the Sironcha beds in natural sequence. The sections and exposures of rock in this part of the country are not continuous, as they are covered up in the most disappointing way by alluvium, and there is the fault just mentioned; still a certain connexion of the Sironcha beds with others in the Kota-Maleri field is apparent, which will always, until fossil evidence be found, cast a shadow of doubt over the grouping and mapping of this series.

As it happens, the Anáram beds are not traceable in the Arjunguta outcrop, but they may be followed down by the right bank of the Pranhita to a point east-north-east of the hill-station, where the outcrop ceases suddenly, there being nothing hence for a mile or so but the high alluvial bank of the river, which bays inland for some distance, lapping round the slopes of the Arjunguta high ground. Not only is there this abrupt ending of the strata, but, after pursuing an even course with a lie of 20° to 30° to the east-north-east, they suddenly show signs of a sharp bend to the south-south-east, with rough slickensides and much silicious and ferruginous infiltration. Nearly all safe signs of lamination and bedding are obliterated in the strong silicious infiltrations which strike irregularly in a general east-north-east to west-south-west run and nearly vertical dip. From this point to the hill-station there is a decided hard wall or ridge of beds much impregnated with silicious and ferruginous matter in the same irregular strips and seams; Anáram pebble beds, purple shales, clays, and sands forming this wall and lying to the north of it.

An important feature about the Anáram locality is, that in going west-south-west from the village, one passes over softish red lilac and buff sands, pebble beds, shales, clays, &c., having a tolerably regular north-east lie; but after about half a mile the beds become troubled, rather flaggy, hard, and more and more ferruginous, when it becomes gradually apparent that one must now be on Kámthi. Such a succession, in descending order, may be found up any of the nalas to the north-west of Anáram as far as Yedlabundun; and thus there seems

little doubt that the Anáram strata are overlying Kámthis, which, though this is partially concealed and interrupted by the fault, are apparently continued in the Arjunguta hill and at Sironcha. No red Maleri clays come in between the Anáram strata and the Kámthis of Lingapeta, but true red clays occur near Isnai, some 5 or 6 miles west-north-west, serially at a much lower horizon than the Anáram beds.

At Yedlabundun everything is covered up for some miles along the valley of the tributary stream, so that neither the Anáram nor the Lingapeta beds are traceable with any certainty to the north-west, though the Anáram beds seem to be continued in the sandstone belt underlying the great zone of limestones striking away to Mulkalapeta, which, as will be seen further on, I take to be the same as the Kota band.

Thus far, the points gained or advanced in this enquiry are—

First, that my so-called Sironcha sandstones are of lower Gondwána age and probably belong to the Kámthi group. They are extremely like those of Aravi-Somnapali, which are on a horizon corresponding to that of the beds near Porsa, which Mr. Hughes had already determined as Kámthis, a conclusion verified by the fossils I afterwards found in them.

Second, that the Anáram plant shales are locally bottom beds resting on Kámthis, and lower in the Kota-Maleri group than the Kota zone of limestones.

THE KOTA-MALERI GROUP.

The most definite and recognizable strata in the Kota-Maleri series are the limestone bands. Hitherto, we have been under the impression that there might be only one of these, that of Kota itself, of which the outcrop at Itial (on the Jangaon river) was a portion. I have, this season, been at the trouble of looking up all the outcrops of these rocks, and there is now no doubt at all that there are at least three bands or zones; still the evidence is not quite clear as to the course of the Kota outcrop, that is, it is not continuous over the most important parts of the field. Indeed, the whole limestone sub-division, or what I have previously called the Kota group, is so much broken and interrupted near Sironcha that it will perhaps be better to treat of it separately, as it occurs in two areas, to the north-west and to the south-east of that town.

The Pranhita area.

The Kota Band (No. 2).—To the north-west of Sironcha there are, first of all, the historic beds of Kota, a mere isolated outcrop in the left bank of the Pranhita. It is to all appearance the same band as that of Tondala to the east of Sironcha, and it appears again to the north-west as the great band, with similar fish scales, at Katapur, whence it stretches away up to near the bank of the Jangaon river at Parwatipet. The line of the Arjunguta fault may strike across between the Kota and Tondala outcrops, so that it is possible they may not be of the same band, though I think they are, being merely stopped for a short distance, but there seems no reason to doubt that the Kota and Katapur outcrops are of one and the same band.

The Bugarani Band (No. 3).—Towards the Jangaon river and about a mile and half eastward of Parwatipet are some further exposures of limestone in a still higher band, the highest in fact that we know of, but I was not able to detect it to the south-east, except, apparently, spot between Waddaguram and Somtum on the right bank of the Pranhita. This band may also possibly give a doubtful outcrop, noticed last year, as lying below the Chikiala scarps north of Sironcha. No fossils have been seen in this outcrop.

The Metapali Band (No. 1).—This occurs about 2 miles or less to the west of that of Parwatipet, and is thus lower in the series than the Kota band. It is strongest about Metapali, being there about a mile in width, with a very low dip, and thence it is traceable for a long distance to the south-east past Surarum, Katapali, and Busnai, and for 5 or 6 miles further in that direction. To the north-west I could not follow it satisfactorily, but it appears to run straight for Bibra, a short distance north of which are some outcrops of hard dark-colored limestones. So far this band has failed to yield any fossils. The lie of the beds is, however, so very low, often nearly flat, at its north-east end, that I am almost inclined to think that this band may be represented in the Itial outcrop lying much more to the west-north-west.

The limestones of Itial form, to all appearance, a completely isolated outlier of nearly flat or flat-rolling beds resting on red clays associated with a thick series of sandstones, which in their turn overlie the proper reptilian red clays of Maleri. They are thus for this part of the country the lowest true limestone band in the Kota-Maleri group, and certainly in this way they correspond to the Metapali band, which for its known length is also the lowest band, resting also on a sandstone belt overlying the reptilian clays. The Itial beds are fossiliferous, with lepidotus scales.

Between the thin limestone beds, and above and below them, are great thicknesses of rather soft, open textured variegated sandstones, sometimes having strong runs of buff, pink, lilac and white clay galls and rolled lumps, with which are intercalated thin bands of red and chocolate-colored clays. The limestones shade rapidly downwards into the sandstones by calcareous sands and clays, and intercalated with them also are thin seams of bright red clays. If I am right in my surmise that the Anáram beds are continued north-westward past Yedlabundun, then they lie between the Kota and Metapali bands. This places the *Palissya conferta* and *Chirolepis münsteri* of Anáram with the liassic fish of the limestone or Kota sub-division.

A remarkable feature about the stratigraphy of these limestone bands is, that they are not traceable to the north of the Jangaon river, though two of the sandstone belts associated with them and the red clays are continued on to the Wardha river. Of course this non-appearance of outcrops may be due to the very thick covering deposits of the Jangaon valley; but the probability is, I think, that they have thinned out, and that their flatter lie allowed of greater erosion, only one isolated patch of the lowest band being left.

The lie of the beds is generally very low, from 2° to 3° , though the outcrops are often broad and marked, giving an idea of great thickness. For instance, the most steady and fair outcrop of good massive limestone beds, in the Kota band

near Katapur, cannot be much less than 800 yards wide, which at an average dip of 5° would only give about 200 feet for the thickness. The limestone is usually a grey compact hard splintery rock, rather clayey or earthy, with many seams of white chert; in fact, it appears to have been originally a fine calcareous mud.

The limestone series comes suddenly or decidedly over the Maleri clays by the presence of distinct bands of limestone strata. I could not, however, ascertain in this Pranhita field that this upper member is fairly separable from the Maleri clays except by a sort of overlap, at either end of the field, of the sandstone below the Metapali-Itial band, and that the red clays have their distinctive rubbly calcareous sandstone, just as the upper member has its distinctive bands of limestone. I do not recollect a single instance of rubbly calcareous sandstones in the upper member; but there certainly is a shading of the calcareous elements throughout the group as from distinct river deposits to others of a more estuarine character.

The Metapali-Itial limestones overlie soft variegated sandstones with many thin intercalated beds of red, white, and greenish clays, and a band (or perhaps bands) of dark grey calcareous sandstone, massive and compact, putting on, on weathered surfaces, a guise of limestone so strongly that it must be hammered at to distinguish it from the true rock. Neither is it the rubbly calcareous rock of the red clays. It may be considered as a kind of passage rock deposited in the period of change in the character of the waters of the Kota-Maleri basin. This calcareous grit is very constant in the sandstones below the Metapali band, all round (starting from the Itial end) by Rajaram, Sardapur, and Bamena, and so down to Kondampeta. It shows again in force, but somewhat sub-divided, in the thick series of sandstones underlying the Itial limestone and spreading out to the west-north-west up to the Jangaon river from Gungapur.

In following the limestone member to the south-eastward, the Metapali band seems to thin out, though the sandstones above and below it are in force to the tributary nala flowing down towards Yedlabundun. This thinning out may, however, only be apparent, for it is wonderful how these limestone bands are hid beneath the more recent deposits, the débris from the outcrops of the associated sandstone belts being enormously spread over the country.

At any rate, at or near Sironcha, the only band carrying the Kota-Maleris into the Godavari area is that of Tondala, which I take to be of the Kota band, and it is in very close proximity to the Sironcha sandstones.

The Godavari area.

The Kota-Maleris, or perhaps more properly the limestone or Kota member of the group, has been traced out in this direction with somewhat more detail, but there are awkward breaks in continuity of strike, and a very large area to the south of the Indrávati bend of the Godavari is either covered up by superficial deposits, or too shut up by jungle for close survey.

I carried the Tondala outcrop fairly down to Chitur, beyond which village there is no further trace of such rocks until within a couple of miles of

Assaralli; but these beds are shifted out of what would be the course of the band, and very possibly belong to the uppermost Bagarāni zone.

The Tondala outcrop is underlaid by the Sironcha sandstones as far as Chitur, where the latter also end abruptly at an east-west fault, and are succeeded in their strike by two fresh outcrops of limestone. The nearest of these to that of Assaralli is a rather broad and distinct one, running down to Ankissa. This is of the usual Kota stamp, and I take it as corresponding to that outcrop, though no fossils were found in it.

Some 3 miles further west a very strong and rather broad band of limestones occurs close to Ardium, and thence it is continued south-east to the left or north bank of the Godavari. There was no yield of fossils here, but this band must, I think, be looked on as answering to that of Metapali-Itial in the Pranhita area. The feature of this outcrop is, that it is unmistakably faulted against Sironchas, while it rests on sandstones, clays and shales of the Kota-Maleri type.

The great east-west or Indrávati reach of the Godavari presents a blank of new alluvial deposits, but on the right or opposite bank two broad spreads of fossiliferous limestone are again met with which must be continuations of those at Ankissa and Ardium.

The Assaralli outcrop could not be expected to appear, as it must have trended under the Chikiala sandstones of Woraguram. However, to the west of this village, there is a great show of strong beds, for about a mile in width, implying a thickness of 448 feet at least; and in a tumbled outcrop of these I found a fine skeleton of a fish and matted masses of scales. Here also are two thin seams of carbonaceous shale, an accompaniment which adds further to the identification of this as the Kota band. In the broad outcrop of thick-bedded limestones, I obtained a few specimens of fish and saw many others which could not, however, be chiselled from the huge blocks of hard splintery rock. This band could not be followed further south than Palmela owing to the covering gravels and sands.

Three miles further westward there is again a wide belt of limestones having its western edge near Lankalagada, in which a few more fish-remains were found. Here, again, the beds are faulted against sandstones forming the bank of the river, the north-north-east dipping strata being bent down to the southward at the Lankalagada end of the fault. The line of fault is not very clear, but it was more or less east and west, rather to the south of east. The limestones, like those of Ardium, overlie sandstones, which must be considered as of the Kota-Maleri group. The sandstones on the north side of the fault, and forming the bank of the river, are, I think, Kámthis.

This outcrop is traceable south as far as Sigampali, and beyond this only faint traces of limestone occur near Redipali and towards Ahilapuram, where the Kota-Maleri strata trend close on the Kámthis of the ridge south of the village; but there is no section showing the relation of the two groups.

In this southern portion of the field, there are no strata answering exactly to the Maleri member of the group, or the proper Red-clay sub-division; but

it is probable that there is a great thickening out of the sandstones below the Ardium-Lankalagada outcrop.

Certainly there are neither sandstones nor clays answering in any way to the Maleris between the Tondála-Chitur outcrop and the Sironcha beds, though such may have been thrown down by a north-west to south-east fault, else may be hidden under the Tondála beds and deposited against a steep face of Sironcha. I could see no trace of a fault along this line, or running from either end into the Maleri country or south-eastwards to Assaralli; hence it would seem as if a natural, though very abrupt, boundary were the simpler interpretation of this unusual association of the Uppér and Lower Gondwánas.

But this is an association implying strong unconformity, such as might be expected to occur under the marked overlap pointed out by Mr. Hughes as existing between the Kota-Maleris and Kámthis.

The Ardium limestones overlie a set of sandstones which are very well displayed in the river bank going towards Aipeta. Proceeding up along the river bank, these thick-bedded sandstones are succeeded by a good thickness of variegated beds, and then by irregular bands of greenish-white clays, calcareous sandy clays and shales, and rough rubbly marly-looking bands with recurrent white and light-colored arenaceous beds and other harder seams of sandstone, all having rather a calcareous constitution; and then there are traces of thin chocolate clays coming in towards the top and underneath the limestones. There are also beds of about a foot thick of calcareous grits with small lumps of greenish and red clays.

These are very much the style of rocks overlying the Kota limestones, and, indeed, such as appear here and there, only much less freely exposed, associated above and below all the limestone outcrops; but there are no signs of the bright red-clay series.

Immediately north of the small hamlet of Madagam on the opposite bank of the river, there is a good outcrop of beds like those on the Ardium side; but their ends are faulted against a stronger outcrop of arenaceous beds immediately under the village, in a nearly east-west line. The beds on the north side are much seamed with nearly vertical east-west veins and strings of silicious constitution, the result being that the outcrop is more a series of hard ridges in this direction, giving an appearance of bedding, while close to the fault itself the ends of the strata are turned down to the northward with slickensided faces having a dip of 70°.

In the absence of fossils and any very decided lithological characters, it is, of course, impossible to say that the Madagam beds on the south side are really of a different group or series to those on the north side of the fault; but they certainly appeared to me to have more of a Kámthi facies, and to be the same as the beds further down the river side near Lankalagada.

I have already, in previous progress reports, given an account of the strata underlying the Lankalagada limestone, describing them as of the Kota-Maleri group. They are all sandstones with a few thin bands of red clay, and low down in them is a thin calcareous band showing scarcely a fair limestone flag. Now

that I have had an opportunity of examining the Maleri field more closely, I may say that these rocks remind me very much of those underlying the southern portion of the Matapali-Itial limestone band.

Thus far I can write of those southern beds, and the apparent absence or non-existence of any red-clay series; but as the country has not yielded to me any evidence as to the boundary, except that there must be one in the approximate line I have drawn south-eastward from Madapur, I cannot say that the Maleri clays may not be hidden by faulting, or along an old steep shore edge. There is no doubt that the country above this reach of the Godavari is a good deal cut up by dislocation, more generally in the east-west line, and there are indications of steep shore edges.

As bearing on this, however, it may be as well not to leave out of notice a very exceptional occurrence of red and green clays some miles further south, right in the centre of one of the most unfrequented parts of this largest jungle waste in the Nizam's dominions. About 13 miles south of Ahilapuram, while working over an immense succession of ferruginous sandstones which must be reckoned as Kámthis (though I have hitherto always strained at an upper Gondwána place for them, owing to their Sironcha facies) on the Kondaparty stream I suddenly came on high banks of red clays with green and white seams and partings of the well-known Maleri type. I tried all I could to carry this outcrop into some sort of relation with the coarse-brown sandstones in the adjacent jungle, but without success; and I can only now record its occurrence, with the surmise that it is left there in the midst of Kámthi strata by faulting, or possibly as an outlying patch.

Before turning north again to discover more closely the further evidence which has been obtained of the red-clay series, it will be as well again to note the points which have been gained or advanced so far—

1. The Kota-Maleri group may be considered to consist of two members, an upper division characterized by having three well-marked limestone zones, two of which contain fish-remains having liassic affinities, and a lower division characterized by a strong development of red clays with remains of reptiles and fishes of triassic age. This marked difference of age of animal remains in what appears to be one group of a formation is now partly accounted for in the fact that the rocks containing one set are decidedly higher in the group than the rocks containing the other; and as there is still a certain amount of hesitation¹ exhibited by my colleagues in their writings on this single point, I may be excused for reiterating this important feature in the stratigraphy of the Kota-Maleris.

2. In the southern or Godavari area of the Kota-Maleris, the sandstones below the lowest band of limestones have thickened out enormously; and there is no known outcrop answering well to the Maleri clays.

¹ See Mr. Hughes' Rec. Geol. Survey of India, Vol. XI, Part 1, page 25, line 34, *et seq.*, W. T. Blanford, Palæontologia Indica, Ser. IV—2, page 20, line 32, *et seq.* I never considered that the Kota limestone is a band intercalated in the Maleris, though I did agree with Hughes that the two might be of the one group. Again, in the Manual of the Geology of India, page xxiv, line 9, *et seq.*

3. The lower Gondwánas of Sironcha town are succeeded directly by a limestone band of the upper division, either naturally, but abruptly, or less probably by a faulted boundary; but this would only be evidence of unconformity between the lower and upper Gondwánas and not, as I have hitherto supposed, of a break between the two members of the Kota-Maleri.

4. The Anáram sandstones with *Palissya conferta* and *Chirolepis münsteri*, are to all appearance on a horizon between the Kota and Metapali-Itial limestone zones.

One more point of evidence bearing on the relations of the limestone member has been obtained in the Angrezpali patch, which may traverse Mr. Hughes' surmise that the red clays there are on a higher horizon than those of Maleri: for I have found limestones of the Kota type lying just along the southern edge of this patch of clays, on the right bank of the Godavari to the east of Damarakunta, between Malarim and Gondapali. The association is, as usual, not at all clear owing to the covering alluvial deposits of the river; but there is no doubt of the limestone being there associated with sandstones overlying the red clays.

THE MALERI RED CLAYS.

I took up these at the typical exposure on the Wardha river near Porsa, and so carried them southwards, without continuity, but to all appearance and by associated sandstones, towards the Jangaon valley, whence they are more easily followed into the proper Maleri field. The Porsa red-clays, however, run under, or to write more correctly, run close up to, and must eventually underlie, sandstones belonging to the belt above the Kota zone of limestones. There is no sign of, nor can there be any room for, the sandstones below that zone, or for the Itial band. There certainly seems to be at this end of the field evidence of a cessation of deposition over the northern frontier of the red-clay basin, which portion was, however, eventually covered up by the later belts of the Kota member (the third sandstone belt, that of Sarwai and Sarsal ridges). This, of course, is virtually only an overlap of these sandstones, not necessarily of the whole limestone sub-division; but there is further evidence yet to come of the possible overlap of the whole sub-division at the Anáram end of the field.

To the south of the Jangaon river, the red-clays show in all their decided outspread; a fair series, displayed more especially about Nambala, Komreli, and Achlapur, of south-eastward dipping red clay bands with intercalations of thin arenaceous beds, and more particularly many bands of grey rubbly calcareous sandstones with indured red, chocolate, and greenish lumps of clay. The reptilian remains must have come from beds in the Maleri field, and not from any higher bands of clay in the upper member, the drainage being all to eastward. The eastern edge of the clay basin runs from a little south of Nangaon past Gungapur, Wodala, Venkatapur, Kasnapali, and Nakalapali to Isnai tank, some 7 miles west-north-west of Anáram. Mr. Hughes, in his small map,¹ carries the western boundary of the clays rather more to the westward than I would have it, but there is certainly a section between Naneala and Rebni showing

¹ Rec., Vol. XI, pt. 1.

that the clays lap over and round brown sandstones and pebble beds (striking north-west to south-east) of unmistakable Kámthi type with ferruginous warts and fungoid segregations. Mr. Hughes' boundary does not run down as far as Isnai, but my having carried it so far is an important point as fetching the lower Gondwána boundary down more to the westward of Anáram with a less easy curve round the Kámthis of Linganapeta.

Along their eastern edge, the red clays suddenly become less persistent, and are succeeded by variegated sandstones with intercalated clay seams, and then by a thick series of thick-bedded sandstones which is perhaps most clearly developed in the fine cliffs, of 60 to 80 feet high, south of Gungapur, and this set of beds may be followed towards Naogaon, or south-eastwards past Akalapali, Kesapur, Sardapur, Bamera, and Kondampeta. The red clays undoubtedly now cease to be the feature, though thinner and thinner seams show as these Gungapur sandstones are followed up; but at the top of them and immediately under the limestones of Itial is a red clay band, next a thin band of limestone, then red clays again, and then the thick zone of limestones. The difficulty is—considering that we have never found any of the Maleri reptilian and fish remains *in situ*—to say from which bed these were derived. The calcareous, or rubbly calcareous sandstone, or even coarse white grit, usually attached to the specimens, would imply that they come from the bands of these rocks in the red clays, and that is at a horizon entirely lower than the Gungapur sandstones: I am also strongly inclined to consider that this is really the case.

From Venkatapur southwards, the Gungapur sandstones, or what I take to be the representatives of them, show above the middle the strong calcareous grit, simulating limestone, already referred to, and I think this seam may be traced down as far as Kondampeta at least; indeed it appeared to me that it runs down even as far south as the parallel of Isnai. West-south-west of Venkatapur, towards Naogaon, &c., I did not find the one calcareous band of grits so clear; there appeared to be more than one band.

The Gungapur sandstones pass along by Naogaon, forming one group with the thick bedded rocks of Aksapur, and I think, those of Chirákúnt, Belgaon, and Balánpur, from all of which Hughes obtained the fossils enumerated in his paper.

Hughes says (*l.c.*, p. 28) of these fossils and the localities—

“In the neighbourhood of Idlara there are the unmistakable red clays with lenticular layers of greyish green granular argillaceous sandstones, and sandstones with clay galls, of the Kota-Maleri group. Thence to the south as far as the range of hills capped by trap, there is no interruption to the series; and at a short distance up the north face of the range and about a mile and a half of Chirákúnt, soft, pale yellow, fossiliferous shales occur that yielded the few species of ferns, cycads, and conifers, &c.” “The same plant (*Palissya conferta*) was discovered in 1872 by Mr. Fedden between Mólár and Balánpur, west of Jangaon, in sandstones which I have included as Kota-Maleris.” The shales and sandstones near Naogaon (in which I last year discovered *Palissya jabalpurensis* and *Araucarites kachensis*) are also components of the group. They may be higher in the series than the Mólár Balánpur beds, their plant forms sug-

gesting this surmise. I cannot adduce any stratigraphical evidence that bears upon the relationship of the Naogaon and Móhár-Balánpur or Chirá-kúnt beds, for sections are of the most broken and uninformative character throughout the whole of the valley of the Jangaon river.

I was not able to visit the Chirá-kúnt locality, but the whole stratigraphic features seemed to me to indicate that there might be a set of rocks, over the red clays, corresponding to the sandstones of Naogaon, for the lie of both sandstones and underlying red clays is very low or nearly flat over this part of the valley, and the fossils were obtained from a spot a short distance up the side of the hill range. The Móhár and Balánpur fossils were found in sandstones apparently above the red clays; and I have not the smallest doubt but that these rocks answer to those of Naogaon, Aksapur, &c., in fact they belong to the Gungapur sandstones, that is, are above the fossiliferous red clays. Hughes is right about their being in the Kota-Maleri group; but it is highly important that their horizon in this group should be known; and there is this fact certainly, that the Naogaon beds at any rate are Gungapurs, and that the Gungapurs are above the proper red clays.

Having so far made out a little more as to the horizon of the plant beds of the Jangaon valley, it would be a most important gain if they could be placed in accord with the Anáram beds to the south-east. I can, I think, carry the Gungapur sandstone zone down as far as Kondampeta, whence certainly it may have curved round to the east-south-east, and so form the Anáram strata too, thus lapping over the red clays of Isnai on to the Kámthis of Lingánapeta. This seems a not untoward lie of the strata, and it is a very tempting position to place them in, as it would give a strong point in favor of the overlap indicated in the Wardha valley; but I cannot satisfy myself on this point. The several bands of sandstone and limestone above the red clays appeared to me to be all running south-east right at the Lingánapeta ground. There is, however, a lower lie and a strike round more to the eastward in the rocks about a mile and a half or two miles north of the latter village, and the red clays spread out rather to the south-east of Isnai, so that there may really be a trend round towards Yodlabundun. In the meantime, I prefer to think that the limestone member of the Kota-Maleris does not thin out so easily near Isnai, and that the Anáram beds' position is between the Kota and Itial-Metapali band of limestones.

The point I would now suggest is, that we have here, at the Isnai end of the Maleri field, tolerably present in evidence that the red clays are being well overlapped by higher and higher strata of the limestone member between Isnai and Anáram.

For the whole field of Kota-Maleris, the various points gained or suggested may be summarized thus—

The series appears fairly separable into two groups, the Maleris and the Kotas, which have already been referred to in this paper as the Red-clay and Limestone members. The Red-clay or Maleri sub-group is overlapped at its northern end, between the Jangaon and Wardha rivers, by an upper sandstone zone of the limestone or Kota sub-group; and even before the doubtful boundary between the sandstones of Sironcha and the Kota limestone is reached to the

southward the same clays are again overlapped by the Anáram strata: while they do not appear to be represented in the southern or Godavari portion of the field.

This separation by overlap accords in some measure with what is known of the animal remains found in either.

The position of the plant-remains is less clear, but that of the Naogaon and Anáram, and perhaps of the Balánpur fossils is above the red-clays, there being overlap in the Anáram case. The plant-shales are in sandstones which run with the red clays up the Jangaon valley, but this, the Gungapur band of arenaceous strata, does not appear to be represented on the Wardha river, the clays there being overlaid by strata to all appearance higher than the Kota zone of limestone; hence we may infer that the Gungapur beds are not co-extensive with the clay series at the northern end, while they overlap it at the other end of the field. On either view of the horizon of the Anáram plant-shales, either as a thinned-out end of the Gungapur beds, or as of the arenaceous zone between the Itial and Kota limestones, their position is still above the clays. I have endeavoured to explain the positions of the Chiráakúnt shales as being also above the clays.

The great difficulty lies in saying where the Maleris are to be considered as ending, and where the Kotas begin. I am fairly at a loss in the proper Maleri field itself, for there are no known sections giving the relations of the two subdivisions. I think the Kotas must be considered as commencing with the Gungapur sandstones even though there be so many thin seams of red clay in that set of rocks as well as up into the limestone zones. The Gungapur beds are thick, and in their constitution they point, on the whole, to a kind of deposition totally different to that of the red clay series, after which a great change must have taken place in the drainage system of the country bordering the Maleri basin; while the successive overlapping of the succeeding deposits on the clays at the northern end of the field indicates a long period of unrepresented time during which the change in animal life might have taken place.

I would then only modify Mr. Hughes' latest classification of the upper Gondwánas so far as to break up his Kota-Maleris into two of the groups proposed in my original provisional list, which are themselves also modified, inasmuch as the Anáram beds are now ranged in the Kota group instead of with the Sironcha sandstones.

CHIKIALA SANDSTONES.

These were followed out to their bounds in this area, but without giving any more evidence as to their relations with the Kotas. However, until more is known of them, it will be better to leave my old correlation of them with the Tripati sandstones of the lower Godavari Upper Gondwánas as a very open question. In some respects they are even like the much newer and tertiary Rájahmandri sandstones of that region. My arguments as to the age of the Balánpur beds will show that I do not think they are at all recognizable by position as Chikialas.

GEOLOGY OF LADÁK AND NEIGHBOURING DISTRICTS, BEING FOURTH NOTICE OF GEOLOGY OF KASHMÍR AND NEIGHBOURING TERRITORIES, *by* R. LYDEKKER, B.A., *Geological Survey of India.*

(WITH A MAP).

INTRODUCTION.

The portion of the Himalaya geologically examined by myself during the past summer comprises the country on and adjoining the main road from Kashmír to Leh, a considerable portion of Drás, Zánkár, and Ladák; the regions about the Pangong Lake and Cháng-Chenmo, and a part of Rupsu and Kulu.

A considerable portion of this area has been already traversed by the late Dr. Stoliczka, and the serial position of most of the rock-groups occurring therein approximately determined.¹ Dr. Stoliczka's survey was, however, mainly confined to the high-roads, while my own embraces a large extent of the surrounding country. I am, therefore, able to present a fairly complete general map of the greater part of the districts in question, in place of the isolated rock-groups colored in by Dr. Stoliczka. My own more extended observations have also led to certain modifications of the views entertained by Dr. Stoliczka as to the relative ages of some of the rocks in these regions, but on the main I agree with the conclusions arrived at by our former colleague. I may also add that I am indebted to Dr. Stoliczka's notes for some of the boundaries shown on the map.

In my previous papers on the geology of the Kashmír Himalaya,² I have generally treated the subject in the manner of an itinerary; describing the different rocks as they occurred on my various routes. This method of treatment, however, would not be suitable to the present area, and I, therefore, propose to treat of each group of rocks by itself.

In geologically mapping an area which consists in the main of exceedingly lofty mountains and elevated valleys, it is of course impossible from the nature of the ground, to be always perfectly accurate in tracing continuously the boundaries of the various rock-groups; not unfrequently, therefore, in my map when such boundaries are far removed from the roads, they must be considered merely as more or less accurate approximations connecting the fixed points where the boundaries cross or approximate to the practicable roads, or accessible regions.

I shall divide my subject into four main headings, *viz.* (1), the older Palæozoics of Drás and Ladák, (2), the rocks north of Cháng-Chenmo, (3), the rocks of the Zánkár and Ladák basin, and (4), the rocks of Lahúl and Kulu, while in a fifth section I shall make some more general remarks on the relations of the rocks of the whole area.

I once again have to deplore the absence of any trace of fossils in the older Palæozoics of the region surveyed, which absence precludes any minute sub-

¹ Mem. Geol. Surv. India, Vol. V, pp. 132, 337. Scientific results of Second Yarkand Mission : Geology.

² Rec. Geol. Surv. India, Vols. IX, XI, XII.

divisions or correlations of the rock-groups, and which also renders the interpretations of their age open to a certain amount of doubt.

In mentioning the names of places in Ladák, I have generally made use of the Tibetan name "Lá" for a pass and "Tso" for a lake; thus, "Kangi Lá" for "Kangi Pass," and "Tso Moriri" for Moriri Lake. This avoids such barbarous repetitions as *Kangi Lá Pass* and *Tso Moriri Lake*, which one sometimes meets with.

With regard to the propriety of applying the names of the European rock series to the rocks of the Himalaya, in cases where no fossil evidence is available, it appears to me that, since we have in the Himalaya some of the rock-groups clearly indicated as being the homotaxial equivalents of European rocks-groups, it is simpler to apply provisionally to the rocks underlying and overlying such known horizons, the same names as are applied to the similarly placed rocks of Europe. I wish, however, at the same time, as I have observed elsewhere, to impress on the reader most distinctly that I do not for one moment consider that any of the Himalayan rocks are exactly equivalent, either in thickness or in time of deposition, with the correlated European rocks; but that I merely indicate that the rock sequence in the two regions generally follows the same order. It would be equally easy for me to invent new terms for each and every Himalayan rock-group; but it appears to me that when my meaning can be equally well conveyed by the use (in a wide sense) of well-known and well established terms, that it is far preferable to employ such terms than to add to the list of new and little-known ones, which already cumber the paths of science to such an appalling extent.

I.—OLDER PALÆOZOICS OF DRÁS AND LADÁK.

In my last published paper on Himalayan Geology,¹ I have stated that the jaspideous, trappoid and slaty rocks occurring in the neighbourhood of Drás, are found, if traced to the westward into the valley of the Kishenganga, to underlie the limestones of the Carbo-Triassic series, and also to correspond in mineralogical composition to the rocks of the Pír Panjál. It may, therefore, be assumed that both the Drás and Pír Panjál rocks are of pre-carboniferous age, and that they in all probability roughly approximate to the Silurian.²

Taking now the Drás Silurian rocks as our starting point, and proceeding in a north-easterly direction along the Ladák road, we shall find that these same

¹ Rec. Geol. Surv. India, Vol. XII, p. 20.

² This conclusion will be confirmed in the sequel. Dr. Stoliczka (Geology of 2nd Yarkand Mission, p. 12) compares these Drás rocks to the trappoid rocks of Srinagar, and considers them as certainly the same; from page 16 of the same work we learn that Stoliczka considered the Srinagar rocks, like similar rocks in Cháng-Chenmo, as Silurian. In a former paper (Mem. Geol. Surv., India, Vol. V, p. 349), he considered part of the Drás rocks as Carboniferous.

In the first of these two papers, Stoliczka appears to have considered that the slaty rocks of Drás underlay the Trias dolomites of the Drás river and Mataian, while in his last notes he appears to have considered (as I do) the junction a faulted one; this would account for the two ages assigned to the Drás slaty rocks. In classing them all as Silurian, Dr. Stoliczka's last conclusions agree with my own. In these last notes he also considers the Trias nearest the Drás slates as the newer (Para), whereas in the first paper he classed it as the older (Lilang).

slates and other rocks are continued about as far as the village of Dandál. In this district, these rocks are frequently jaspideous like those on the road from Drás to Tilel (Tilail) described in my above-quoted paper, and they often acquire a black "river-glazing," while they disintegrate into a dark and heavy iron-sand. Occasional beds of the true slates are highly ferruginous and weather to a rusty-red color: there also sometimes occur thin beds of a coarse conglomerate resembling that found among the slates of the Pír Panjál, the occurrence of which confirms the identity of the rocks of the two districts: near Drás the rock is like some of the trappoid rocks of Kashmír.

Still following the course of the Drás river, we find, below Dandál, the rocks gradually assuming a hornblendic character, and not unfrequently containing crystals of pure hornblende of a large size. Near the halting place of Tashgám, the strata are thrown into several small anticlinals, the lowest exposed beds consisting of a dark-colored syenitic gneiss,¹ while the higher beds consist of the Drás slaty rocks: from the latter to the former, there is a complete and imperceptible passage through the above-mentioned hornblendic rocks, so that I come to the conclusion that the lower part of the slate-series has here been altered into gneiss.

From Tashgám to near the junction of the Drás with the Shingo-Shigar river we have alternations of small gneiss anticlinals overlaid by slaty rocks. Some of the latter closely resemble in their mineralogical characters the massive bluish rocks of the Panjál series, which occur at and near Shísha-Nág in Kashmír,² while others are like the ferruginous slate rocks of Drás.

Near the junction of the two rivers mentioned above, we come upon a massive light-colored syenitic gneiss (syenitoidite) which seems to underlie conformably the transition rocks.

Another ridge of the same (generally syenitic) gneiss occurs immediately to the north of Drás, apparently underlying the slates of Drás on the one side, and the transitional rocks of Tashgám on the other. I have not traced these rocks far to the north-west of the Ladák road, but I have already mentioned³ that gneiss pebbles occur in the Búrzil river on the Kashmír and Astor road; and General Cunningham⁴ also states that the table-land of Deosai or Deotsu (to the north-west of my map), consists principally of granite, by which he doubtless means the same gneiss: there is, therefore, every probability that a continuous band of these crystallines extends to the north-west of Drás and Kargil. The eastward extension of this Deosai and Drás gneiss will be described below.

The gneiss anticlinals near Tashgám are probably the highest beds of the main gneiss ridges, and are frequently dark colored; but as the main mass of the rocks between the two ridges of gneiss are the same as the slates of Drás, they have been colored of the same tint in the map. We shall, however, subsequently

¹ The whole of the north-western Himalayan gneiss which I have seen, whether hornblendic or micaceous, is granitic in structure, and never distinctly foliated. The hornblendic variety may be termed "syenitoidite," and the micaceous "granitoidite."

² Rec. Geol. Surv. India, Vol. XI, p. 44.

³ Rec. Geol. Surv. India, Vol. XII, p. 24.

⁴ "Ladák," p. 57.

see that in Ladák portions of the slate series are sometimes locally altered into a dark-colored gneiss which overlies the massive lighter-colored gneiss, and the same may not improbably be the case with the Tashgám rocks.

To the eastward of Drás, the slaty rocks may be traced across the Suru river as far as a line running nearly from north-west to south-east through Múllhet-rúng Station, where the rocks of the great Triassic series appear to be faulted against them. To the south and south-east the same slates overlie the gneiss of Suru and Rúndúm, and were identified by Dr. Stoliczka as undoubted Silurians. If, as I infer from Dr. Stoliczka's notes, the gneiss of Suru is overlaid conformably by the slates, the former may probably be the same as the gneiss of Drás and the Shingo-Shigar river: this question will be discussed more fully in the sequel. The Suru Silurian slates have been traced by Dr. Stoliczka in a band running south-south-east from Rúndúm to the south of Zánskar, and are there continuous with those of North Lahúl and Spiti, which will be referred to again in the third section of this paper.

Returning to the main axis of gneiss to the north of Tashgám, I proceed to trace its eastward extension, and to consider its relations to other rocks to the east. From the junction of the Drás with the Shingo-Shigar river, the gneiss extends to the south-east as far as Kargil and Chattu, where it is overlaid by the Tertiary series. From Kargil I have traced the gneiss down the Suru and Drás rivers as far as the Indus, but did not reach its northern limit. The gneiss in this district is sometimes fine-grained and dark-colored, and at other times coarse-grained and light-colored. At Kargil a very massive light-colored gneiss, without any trace of stratification, underlies the darker and more distinctly stratified upper gneiss.

From Kargil the southern boundary of the crystalline series runs in a generally south-easterly direction.¹ It keeps to the south of the Indus till near the village of Dorgu, when it crosses to the northern bank. To the eastward of Dorgu the boundary forms a sinuous line along the bed of the Indus for some miles; it then runs at some distance to the north of the river, passing close to the villages of Skining, Pharka, Himis, and Ling: from the last-named place the boundary bears to the south-east, till it again joins the Indus at Pittak, south of Leh. To the south-east of Pittak the southern boundary of the crystallines follows approximately the course of the Indus, generally running somewhat to the north, and has been traced as far as a point due south of the Pangúr Lake.

It now remains to say something of the composition, and relations to other rocks, of the Ladák crystallines.

To the south-east of Kargil along the Indus valley the gneiss usually consists of the light-colored massive variety, and has generally a north-easterly dip, so that the older beds appear along the valley of the Indus and the newer towards the top of the Kailás range.

The composition of the rock varies considerably; in most cases, indeed, the

¹ The range on the right bank of the Indus in Ladák has been termed by General Cunningham ("Ladak," p. 43) the "Kailás range," a name which I adopt here: in the "Manual of the Geology of India" this range is called the "Ladák range." This range forms a dominant branch of the range north of the Manasarowar Lake.

rock is a true syenitic gneiss, consisting of quartz felspar and hornblende. This is, however, not always the case, since I have already shown¹ that the gneiss of Drás has a true granitic composition, consisting of quartz, felspar, and two kinds of mica. Near the village of Himis, to the west of Leh, I collected the following varieties of crystalline rocks,² viz.—

Gneiss.	Mica in small flakes.	(Granitoidite.)
Syenitic gneiss:	a. Pink orthoclase.	(Syenitoidite.)
	b. White do.	
Pegmatitic gneiss.		(Pegmatoidite.)
Hornblende rock	a. Small crystals of Hornblende.	
	b. Large ditto.	

The hornblende rock usually occurs in small irregular patches.

At Tánkse, 40 miles to the east of Leh, the greater portion of the gneiss is porphyritic, containing numerous crystals of white orthoclase; near Shushál, 45 miles to the south-east, the orthoclase is pink colored. In the Chimray valley, on the Leh and Tánkse road, the gneiss is traversed in all directions by veins of an intrusive rock, agreeing with some specimens of the albite granite of Dr. Stoliczka. This granite is very light-colored, and consists of quartz, albite felspar, and black mica: the latter occurs in large flakes, and not unfrequently forms a thin coating to quartz crystals of very large size. This albite-granite intrusion is very characteristic of the central gneiss.³

With regard to the relations of the Ladák gneiss to other rocks, the most clear sections are displayed near Tánkse and the Pangong lake, and I accordingly commence with those districts. At Tánkse itself we find the crystalline rock to be a massive white, and generally porphyritic, syenitic-gneiss, the higher beds consisting frequently of alternations of dark and light bands. To the south-east of the village of Chilam, near Tánkse, this porphyritic gneiss is distinctly seen to be overlaid by white and greenish quartzitic sandstones, black and green slates, banded jaspideous rocks, a few conglomerates, and the peculiar massive half-slaty half-sandy rock, so characteristic of the Silurians of the Drás river. The whole of the slaty series, both in structure and in position, exactly resembles the slate series of Drás, and there seems to me but little doubt that they are one and the same series. This slate series forms a long narrow ellipse extending from near Tayár, in a south-easterly direction, to a point south of the Pangúr lake. The centre of this ellipse shows here and there a central core of white non-porphyritic gneiss underlying the slates, and forming the highest peaks of the range.

In the Chilam valley the northern boundary of this ellipse appears to be a faulted one, as on the north side of that valley we have hills of gneiss with a northerly dip, while to the south there are dark slates underlain by gneiss (at the base of valley) with a southerly dip; this fault is apparently continued far

¹ Rec. Geol. Surv. India, Vol. XII, p. 19.

² In his last notes (Geology of 2nd Yarkand Expedition, p. 16), Dr. Stoliczka mentions the varied composition of the Ladák gneiss, which he had previously described as syenitic.

³ Stol.: Mem. Geol. Surv. India, Vol. V, p. 13.

Mc'Mahon: Rec. Geol. Surv. India, Vol. X, p. 221.

to the south-east. To the north-west of Tánkse, the fault, on the other hand, seems to have died out, and the slates appear to rest conformably in a regular synclinal of the gneiss. Taking a transverse section to the south-west from Tánkse *viâ* the Kái Lá, we find to the east of Kái Tso the slate series with a north-easterly dip, underlaid conformably by the white non-porphyrific gneiss of the Indus valley. This gneiss, especially in its higher beds, contains not unfrequently bands of a darker color, as we found to be the case at Tánkse.

Some of the slates, in the middle of the series, between Tánkse and the Kái Lá have been locally altered into a fine-grained, dark-colored, and generally imperfectly crystallized gneiss, quite distinct in character from the underlying white gneiss. Further to the north-west on the road between Tánkse and the Chang Lá, the upper dark gneiss, altered out of the slates, is seen resting on and passing down into the white gneiss of Tánkse. This section, therefore, establishes the important fact that there exists in Ladák gneiss of two distinct ages...one altered out of Silurian slates, and another underlying such slates, but apparently also, at all events partly, altered out of an older conformable series. This fact may lead, as mentioned, to the inference that the darker colored and higher gneiss of Kargil, already referred to, may really very possibly be the altered Silurians, though, as before said, the question cannot at present be definitely settled.

As already stated, the white gneiss of the Indus valley dips generally to the north-east, and the higher beds consequently form the summit of the Kailás range. Along the greater part of the Indus valley in Ladák the white gneiss continues to the crest of the range, but near Leh itself, below the Khárdong Lá¹ and Láswan Lá, we find the white syenitic gneiss overlaid by alternating bands of dark and light-colored gneiss like the higher gneiss of Tánkse and the Kái Lá. This striped gneiss is again succeeded by an imperfectly crystalline, dark-colored, and fine-grained gneiss, alternating with partially altered slaty rocks, and occasional unaltered slates. These rocks appear to occupy a synclinal ellipse in the white gneiss, the boundaries of which are approximately indicated on the map. From the nature and position of these rocks, I have little doubt but that they are the altered equivalents of the slates to the south of Tánkse, and they have been colored accordingly in the map; this is, however, only a conjectural correlation.

To the northward of Leh, the crystalline series has been traced by Dr. Bellew along the Shahidúla and Yarkand road as far as Sá-Sango where it appears to be succeeded by Silurian slates.

Returning once again to the Tánkse district, we find that the range to the south-east of Tánkse, running parallel to the north-western half of the Pangong lake, consists of the porphyritic gneiss of Tánkse. This gneiss I have traced some distance to the south-east of Shushál, where it is overlaid by Silurian slates, connecting those to the south of Tánkse with those of the Pangong lake, which will be referred to immediately. On the northern flank of the

¹ This pass is called on the Topographical Survey maps the Laowchi Lá, though it is always spoken of by the natives as the Khárdong Lá.

Tánkse range, to the north-east of Tánkse, we have a regular ascending series of gneissic rocks. The higher beds become gradually interstratified with unaltered slates and sandstones, with some banded jaspideous rocks; till finally all gneiss disappears, and the series consists solely of slaty and sandstone rocks, corresponding exactly in mineralogical character with the slaty series to the south of Tánkse. The transition from the crystalline to the slate series is, however, here so very gradual that only an arbitrary boundary can be drawn, but the higher gneissic rocks are probably altered Silurians.

The slaty series I have traced to the north-west to the Shyok river, and to the south-east, along the whole length of the Pangong and Pangúr lakes: its north-eastern boundary I shall refer to subsequently. Near Bapi Station to the south-east of the Pangúr lake, the slates are underlaid by a core of granitoid gneiss. We have already seen that to the north-east of Tánkse there is a regular sequence from the crystalline to the slate series; along the south-western shore of the Pangong lake, on the other hand, the junction between the two series seems to be a faulted one, the black slates and green shales and sandstones which form a narrow band along this shore of the lake dipping towards the gneiss. Still further to the south-east the junction again appears to be a normal one. In the mineralogical composition of the rocks surrounding the Pangong lake, there is very great variety, but with one exception they consist mainly of colored slates, shales and sandstones. I have already mentioned the composition of these rocks on the south-western shore of the lake, and need not, therefore, refer to them again. On the opposite shore, in addition to the rocks of the south-western shore, there also occur banded jaspideous rocks, together with the slaty-sandy rock of the Drás river, and true slates which weather to a rusty red color like those in the neighbourhood of Drás, already noticed. The mineralogical composition of these Pangong rocks affords by itself alone abundantly sufficient evidence to show that they are the equivalents of the slate series of Drás and of the country to the south of Tánkse.

At the north-western extremity of the Pangong lake, where the original relations of the rocks have been greatly disturbed by faulting and inversion, there occurs a great local development of a glistening white saccharoid quartzitic sandstone or quartzite, which superiorly gradually becomes calcareous, and passes by imperceptible degrees into a pale blue limestone. This rock overlies the slate series of the Pangong lake, and is apparently faulted against the ridge of gneiss to the south. This very characteristic saccharoid sandstone and limestone is precisely similar in mineralogical composition to the rocks underlying the Triassic series in South Rupsu, which we shall subsequently show to be probably of Carboniferous age. This identification confirms our conclusion as to the Silurian age of the slaty rocks of Pangong and Drás, the former of which underlie the sandstone and limestone.

Some miles to the south-east of the village of Shushál, at the Saki Lá, and elsewhere in the neighbourhood, there occur other outlying masses of blue limestones and white sandstones, which seem undoubtedly to be the same as those at the north-western end of the Pangong lake.

The Pangong slates lie to the north against a ridge of gneiss which runs in the normal Himalayan strike, on the line of the Marsemik pass. To the south-east of the Tatar camp at Chagra, the slates appear to be faulted against the gneiss, but to the north-west of a spur of gneiss running towards the south from Chagra, the slates conformably overlie the gneiss. The highest beds of the gneiss consist of alternations of light and dark bands, some of the latter being garnetiferous, like similarly situated gneiss in Pángi.¹ The gneiss of the Marsemik Lá itself is usually porphyritic like that of Tánkse; to the north-west it is continued to the valley of the Shyok, and to the south-east I have traced it some distance over the border into Chinese Tibet. This ridge of gneiss appears to form an anticlinal axis, since on the north side of the Marsemik Lá it has a north-easterly dip, and is overlaid conformably by slates, sandstones, jaspideous rocks, and the before-mentioned massive, slaty-sandy, or trappoid rock, so characteristic of the Drás Silurians. Many of the higher beds of the crystalline series consist of a dark-colored hornblende rock with bronzite, similar to a rock which occurs in the same position in the Tánkse valley section. These massive trappoid rocks were apparently considered by Dr. Stoliczka² to show some signs of an igneous origin, and also to show some resemblance to the Silurian series of Srinagar; my own opinion is, that none of these rocks are of igneous origin, though they do, undoubtedly, very closely resemble some of the trappoid rocks of the Kashmir Silurian series, some of which have probably been brought to their present condition by metamorphic action.³ From the summit of the Marsemik Lá to the bed of the Cháng-Chenmo river, we have a generally ascending section through these same slaty rocks: a short distance on the north side of the pass, some of these rocks have been locally altered into a dark-colored gneiss, similar in character to that which I have already referred to, as occupying a corresponding position in the Tánkse valley. On the Cháng-Chenmo river, the slate series seems to be faulted against massive Triassic limestones, which I shall notice again in the succeeding section of this paper.

Dr. Stoliczka⁴ seems to have considered that the gneissic rocks of the Marsemik Lá were an altered portion of the slate series of the Cháng-Chenmo valley, and that consequently both were of Silurian age. There appears to me, however, to be a clear case of the superposition of the latter on the former, as in the other sections of similar rocks already described.

The rocks to the south of the Cháng-Chenmo valley, as I have said, were referred by Dr. Stoliczka⁵ to the Silurian. Dr. Stoliczka also compares these rocks to the trappoid rocks of Srinagar, whence we may conclude that he also considered them to be Silurian. Both these rocks are, however, similar in character to those to the south of Drás, which Stoliczka⁶ at first classed as Carboniferous, but which appear to me to be Silurian.

¹ Rec. Geol. Surv. of India, Vol. XI, p. 54.

² Manual of Geology of India, p. 653.

³ See Rec. Geol. Surv. of India, Vol. XI p. 36, *et seq.*

⁴ Geology of Second Yarkand Mission, p. 16.

⁵ *Ibid.*, p. 16.

⁶ Mem. of the Geol. Surv. of India, Vol. V, p. 349.

This completes the description of the older palæozoic rocks of the Drás district, and of the northern bank of the upper Indus, as far as I am at present acquainted with them. A further discussion as to their precise geological age, and as to their relations with the palæozoics of other regions of the Himalaya, will find a more suitable place in the concluding section of this paper.

II.—ROCKS NORTH OF CHANG-CHENMO RIVER.

In the previous section of this paper, I have traced the Drás slaty series as far as the left bank of the Cháng-Chenmo river, where it is separated, by what seems undoubtedly to be a faulted line, from a totally distinct series of rocks which forms the low cliffs on the opposite bank; the two series of rocks occur on a broken anticlinal axis.

The rocks on the right bank of the river are to a great extent composed of the characteristic white Triassic dolomitic limestone so frequently referred to in my former papers: a short distance north of the river, these rocks are traversed by a synclinal axis. The higher beds exposed in this synclinal are hard and crystalline, while the lower beds consist mainly of a soft white dolomite like that of Amnāth cave in the Lidar valley of Kashmir; some soft reddish shales and a brecciated red conglomerate occur locally in the lower beds. *Megalodon* is of common occurrence in these limestones, and Dr. Stoliczka also obtained from them *Dicerocardium*;¹ there can, therefore, be no doubt as to their age.

To the northward these Triassic dolomites are underlaid by carbonaceous shales, not unfrequently containing crinoids and, according to Dr. Stoliczka, furoids, and then again by dark slaty shales, sandstones, and occasional limestone, forming a somewhat folded series. Still further north, these rocks are underlaid by an anticlinal of rocks which seem to be the Silurian Drás series, which, according to Dr. Stoliczka, are again succeeded further north by Carboniferous and Triassic rocks, the latter probably forming the greater part of the dreary plains of Dipsang, to the north of my map.

From the relations of the crinoidal shale and sandstone series to the Trias dolomite, I consider that the former rocks must undoubtedly be considered as of Carboniferous age—an opinion also held by Dr. Stoliczka who noticed their resemblance to the rocks belonging to that period in Spiti.

In the Cháng-Chenmo valley the notes of Dr. Stoliczka² make mention of some sandstones and conglomerates which he doubtfully considers as the representative of the Ladák Eocenes. These rocks are also much mixed with shales, and when I first entered the Cháng-Chenmo valley, I was at once struck with their resemblance to the Tertiaries; the sections are a good deal obscured by debris, but I found a portion of a conglomerate, which is strikingly like the Tertiary conglomerate of Miru (described below), distinctly underlying the Trias dolomite; and I think that these doubtful rocks belong to the Carboniferous series, the strong resemblance of which to the Tertiaries elsewhere will be noticed in the sequel. There are certainly no Eocene rocks on the Pangong lake, such as are

¹ Geology of Second Yarkand Expedition, p. 17.

² *Ibid.*, pp. 17-18.

referred to (probably by some clerical error) in the above-quoted passage from Dr. Stoliczka's notes.

III.—ROCKS OF THE LADÁK AND ZÁNSKÁR BASIN.

I now come to the consideration of a series of rocks mostly newer than those of which I have already treated, which occupy a large elliptical area bounded to the north by the crystalline series described in the last section, and to the west and south by the Silurians which rest on the gneiss of the Zánkár range, already described in a previous paper.¹ The area occupied by these rocks comprehends a considerable portion of Ladák and nearly the whole of Zánkár, together with parts of Rupsu and other districts. As Ladák and Zánkár form the greater part of this area, it may be well termed the "Ladák and Zánkár basin." The whole of this large area has not at present been completely surveyed, owing to the very difficult nature of the country, but sufficient is known to indicate the general distribution of the rocks. I have said that the greater portion of the rocks in this area are newer than those previously treated of; but from the south-eastern extremity of the basin a ridge of older rocks runs up, separating this end of the basin into two divisions. I shall treat of the rocks of this area in their serial order, commencing with the Tertiaries. It may be observed that the long axis of this basin or ellipse has the normal Himalayan north-westerly and south-easterly strike.

The Tertiaries.

The Tertiary series forms the north-eastern band of the area under consideration and, rests immediately on the Ladák crystallines. Coming from the west, these Tertiary rocks are first met with close to the town of Kargil, where they rest unconformably upon a denuded surface of the syenitic gneiss, and have a low and regular dip to the south-east. Masses of the gneiss may here and there be observed within the Tertiary area, protruding through the newer rocks. The lower beds of the Tertiaries near Kargil consist of soft grey and brown sandstones, shales, slates, and limestones, with here and there bands of conglomerate. Near the village of Pashkám the dip of the rocks has increased, being about 40°, and the higher beds, which are here well exhibited, consist of bright purple and green shales and sandstones, with occasional bands of a yellowish sandy limestone.

The northern boundary of the Tertiary zone is continuous with the southern boundary of the Ladák crystallines, and need not be exactly traced, and I, therefore, at once proceed to describe certain sections of the Tertiaries which will best exhibit the general characters of these rocks.

It may, first of all, be observed as a very important point, that along the whole of the northern boundary of these rocks, from Kargil to south of the Pangúr lake, (a distance of nearly 200 miles), the dip of these rocks is to the south-west, and that to the westward of Leh the same dip continues (with an occasional exception) throughout the entire width of the series. For some distance to the west of Leh this dip seldom exceeds 30° or 40°, and is of great regularity,

¹ Rec. Geol. Surv. of India, Vol. XI, p. 52.

and free from contortions. To the east of Leh these rocks, except along the northern border, have undergone a greater amount of disturbance.

The sections which exhibit most clearly the relations of the Tertiaries and the gneiss are found below the point where the Kashmir and Ladák road enters the valley of the Indus at Khalchi. Near the village of Inamdoh the lower Tertiaries, here consisting chiefly of slates and sandstones, are seen resting unconformably upon a denuded escarpment of the gneiss. The surface of the escarpment has an average slope of about 25° to the south-west, this slope being irregular and bearing numerous hillocks and hollows: the dip of the gneiss is to the north-east.

The Tertiaries rest upon this sloping and denuded surface with a dip slightly lower than the plane of the slope. The lowest beds of the Tertiaries, which occur at the base of the slope, are cut off higher up by the projecting hillocks of gneiss, while the higher beds extend considerably further up the slope, thus showing a clear case of overlap. Numerous analogous sections may be seen in the neighbourhood, but the one quoted affords ample evidence to prove that the junction between the two series of rocks is a natural one, and that the Kailás crystalline range formed the old shore line of the gulf in which the Tertiaries were deposited.

I have said that at Inamdoh the lower Tertiaries consist of slates and sandstones; this composition is, however, not constant in the neighbourhood, since we not unfrequently find the lower slates replaced by coarse conglomerates containing rolled pebbles of the crystalline and other rocks. This conglomerate is of great thickness on the Khalchi and Dhúmkar (Dhumkur) streams, and it seems, from here to Leh, to occur on all the tributary streams descending from the Kailás range of crystallines to the Indus, and not in the intervals between such streams. If I am right in this interpretation, and I think I am, we must conclude that the drainage system of the southern side of the gneiss range followed the same approximate lines during the deposition of the Tertiary rocks, as it does at the present time.

A transverse section from north to south of the Tertiaries at Khalchi may be taken as a typical example of the series in this district. The lower beds, as we have already seen, are composed either of conglomerates, grits, sandstones, or slates, according to their relative position to the streams. The sandstones not unfrequently show ripple-mark, and the slates are generally grey in color, very hard, and almost indistinguishable in hand specimens from the palæozoic slates which occur to the south of the Tertiaries. The succeeding zone of beds consists of orange and brown calcareous sandstones, with occasional shales. These are followed by purple and green shales which are almost indistinguishable from some of the Subáthu rocks, and which are well represented on the Indus at Khalchi and Basgo. Between the villages of Kalchi and Nolra, in the Indus valley, a thick band of coarse, blue, shelly limestone overlies the colored shales. This limestone may also be seen on the Kashmir and Ladák road at the junction of the Láma-Yuru stream with the Indus, and again on the Zánskár river to the south of Nímo, so that it doubtless forms a continuous

band. In this limestone near Khalchi¹ I found a species of *Turbo*, and numbers of little disks which I believe to be Nummulites, though their structure is obliterated. On the Zánskár river, on the other hand, nummulites are extremely abundant in this limestone, and water-worn pebbles exhibiting sections of these fossils show the banks of the Indus at Nimo.² The nummulite, which is characteristic of this limestone, is, Mr. Blandford informs me, *N. raymondi*, an Eocene species, which fixes the age of these rocks: this species with *N. exponens* were obtained from these rocks by Dr. Stoliczka.

In the Indus valley between Khalchi and Nimo the nummulitic limestone is overlaid by several feet of a coarse conglomerate, containing pebbles of the underlying limestone: this conglomerate is apparently conformable to the limestone, and is succeeded by shales and slates. The Tertiary sedimentary series near Khalchi may be tabulated as follows:—

UPPER ...	{ Shales and slates. Limestone conglomerate. Nummulitic limestone.
MIDDLE ...	{ Purple and green shales and sandstones. Orange and brown calcareous sandstones and shales.
LOWER ...	Grey and brown slates, sandstones, grits, or conglomerates; the sandstones often ripple-marked.

Such is the normal section of the Eocenes at and below Khalchi: above the latter place, on the other hand, a very different condition prevails in the lower beds. On the Saspúl stream the boundary between the Eocenes and the Palæozoics runs close to the upper Kashmir and Ladák road. The lower Eocenes, which are inclined to the south-west at an angle of about 25°, consist of very soft brown and yellow sandstones, very frequently showing cross-bedding. In these sandstones are embedded vast quantities of blocks of the gneiss of the Kailás range, many of them several feet in diameter. Some of the isolated blocks showed the sandstone strata bending down below them, as if they had been dropped from above on to the still soft sand: two blocks were polished in a manner suggesting ice-action. The soft sandstone, with its boulders, lies unconformably on the gneiss, corresponding in position to the lower slates and conglomerates of the Khalchi section: it is overlaid by harder green shales and the middle Eocenes. Near the village of Ling the lowest strata consist of soft colored gypseous shales with occasional bands of a compact buff limestone; this limestone contains numerous specimens of a large species of *Estheria*; these strata are again overlaid by the purple Subáthu-like rocks. At Nimo again, there occur soft sandstone strata with embedded gneiss blocks, which are very

¹ It is mentioned by Mr. Davidson, in describing some fossils collected in Ladák by Col. (then Capt.) Godwin Austen, (Q. J. G. S. L., Vol. XXII, p. 38) that Hippurites were seen in a rock at a place called Kalatys on the Upper Indus; I think that Kalatys must be the same place as Khalchi, which is also called Kalatse. I should, however, be very much inclined to doubt the occurrence of *Hippurites* either at this place or anywhere else along the Upper Indus, the course of which lies in or near the Tertiaries.

² I spell this name and numerous others without the initial S, which seems generally to be omitted in pronunciation. Similarly, Nolra for S'Nolra, Kio for S'Kio, Tok for S'Tok, Properly also Piti for S'Piti, but the spelling Spiti has acquired a general acceptance.

slightly inclined, but which from their structure seem to correspond with the lower Eocenes of the Saspúl stream; their relations to the higher Eocenes are not, however, well displayed, and to the south-east they are concealed by a modern boulder deposit, which also covers the base of the Tertiary series near Leh, where it has been much denuded away along the valley of the Indus. Above Leh, however, near the village of Arpa, we find the hard gneiss conglomerate occurring low down in the Tertiary series, underlaid along the bed of the Indus by soft gravels, conglomerates, sandstones and clays with a south-westerly dip of about 15° . The conglomerate contains pebbles of a trap, which is thus shown to be of *infra*-Eocene age, but whose origin is not certain: the lowest conglomerate also contains pebbles of blue limestone and buff dolomite probably derived from rocks of the Carbo-Triassic series, and indicating former outcrops of these rocks now probably concealed by the Tertiaries. Occasional blocks of gneiss, several feet in diameter, occur in the sandstones. From the softness of these rocks they have in great part been denuded away by the Indus, and only patches remain here and there.

I can but think that ice-action has played some part in the formation of these lower Eocene strata, as it seems to me very difficult to imagine that water power alone could have placed these blocks in their present position without scouring out the soft sand in which they are embedded. I have, however, no positive proof to bring forward in support of this view.

I will now describe two sections taken across the nummulitics higher up the Indus than the former, the first being an ascending and the second a descending section. The first section is taken from the Indus valley below Leh to Kio in Zánskář. The lowest nummulitics exposed on the Indus near the village of Phay, consist of brown and green sandstones, mingled with coarse conglomerates and grits; the sandstones are often ripple-marked, and the pebbles in the conglomerate consist mainly of gneiss, while the grits are composed of coarse gneissic sand precisely similar to that which at the present time is found in the valley of the Indus. In the higher part of the series, near Urúcha, purple and green shales and slates succeed and partly replace the grits, forming an anticlinal resting upon green and brown splintery shales. The higher slates contain numerous bands of earthy limestone abounding in nummulites: the latter are particularly common near the village of Shingo,¹ where I also obtained a species of *Conus*. The rocks are here much folded, but the foldings are regular and open, and never show the minute contortions and crumplings so characteristic of the older rocks. Some 2 miles above the village of Kio the nummulitic rocks are overlaid by several hundred feet of a coarse conglomerate, which is here nearly vertical. The relation of this conglomerate to the shales is not very clear, but it appears to lie in a synclinal axis, being again underlaid by colored shales nearer Kio; the great mass of purple shales are, however, unrepresented below the conglomerates at Kio; close to the latter place the Tertiaries are underlaid unconformably by Carboniferous rocks. The higher Tertiary conglomerate, here and in other parts of the same line, contains numerous pebbles of the

¹ The village of Shingo is placed in the Atlas Sheet $1\frac{1}{2}$ or 2 miles too near to Kio.

underlying nummuliferous limestone, clearly showing that the former rock is the newest of the Tertiary series.

The next section is taken down the Gía river from Látho to Upshi on the Indus. On the left bank of the river at Látho the upper conglomerates are nearly vertical, but with a slight northerly dip: they rest to the south on green and purple shales, with false bedding, which at first sight has somewhat the appearance of unconformity; this is, however, but a local condition, and on either side conformability is clear. The conglomerates, which can be traced continuously along the southern border of the Tertiary zone from Kio to this point, form a regular synclinal axis, and as they descend gradually alternate with greenish-colored sandstones: they contain pebbles both of the older Tertiary and of the neighbouring Palæozoic rocks. Further down the Gía river, these conglomerates are underlaid by green and red shales, sandstones, grits and conglomerates; and the whole series is much contorted. Near the village of Míru, the highly colored shales are underlaid by a considerable thickness of conglomerate: these conglomerates contain chiefly pebbles of gneiss, of carboniferous quartzitic rock, of some unknown silicious rocks, and irregular fragments of the lower Tertiary shale. This conglomerate has acquired a kind of false slaty-cleavage, splitting into thin plates, right through the pebbles, and parallel to the stratification. Below the conglomerate we find an anticlinal axis of brown and green crumbly shales and greenish sandstones, which are again overlaid, towards the Indus valley, by the red shale series. At the very base of the Míru anticlinal there occur some brown and black carbonaceous shales alternating with bands of quartzite, which correspond so exactly in mineralogical character with the Carboniferous rocks of Gía (see below), that they are, I think, the same. These lower rocks seem to have the same dip as the Tertiaries, and as the two are very similar in mineralogical character, it is not easy to distinguish between them. The great similarity between the Eocene and Carboniferous shales at Shargol will be noticed below. If the identification of these Carboniferous rocks is correct, it would appear that we have here a case of parallelism between these rocks and the Tertiaries, and that the former must have been approximately horizontal at the time of the deposition of the latter.

Below Míru there is an alternating series of red and green shales and sandstones, with occasional bands of gneiss conglomerate. About 2 miles above the village of Upshi, these rocks are underlaid by hard and coarse gneiss conglomerate, several hundred feet in thickness, again underlaid by the softer rocks of the Indus valley, already referred to. No nummulites were met with in this section.

From the preceding sections it seems to me probable that the green and brown crumbly shales of Míru and Urúcha, together with some of the overlying conglomerates, are the equivalents of the lower gneiss conglomerate of the Indus valley, since both these groups are overlaid by the red shale series. It is further not improbable that the red shales once overlapped the gneiss conglomerate in the Indus valley, and extended some distance further up the crystalline rocks of the Kailás range.

It will be noticed that throughout the Tertiary series (above the gneiss con-

glomerates), there is evidence of local contemporaneous denudation, and that the southern conglomerate is formed in part of fragments of the denuded nummulitic zone, which I have shown to be relatively high up in the series. I have also shown that these higher conglomerates are underlaid by only a small thickness of shale, on their southern border, and it, therefore, seems probable that these newer strata overlapped the older along this border, such overlap being possibly due to local subsidence.

It now remains to treat of the southern boundary of the Eocenes, in the course of which we shall have to discuss a large mass of volcanic rocks which occur along this line. Commencing our survey at the western extremity of the zone, we find that the purple shales of Pashkám are overlaid by a great mass of basaltic trap which here consists of greenish anamesite, weathering to a pale brown color. South of Pashkám the traps may be traced continuously to Shargol (Shergol), a width of 10 miles, their western boundary running south-south-east from Kargil and adjoining the Palæozoics of Tashgám. At Shargol we find out of the main trap outflow, a band of soft yellow calcareous sandstones, and purple, green, and black shales, exactly resembling the sedimentary Eocenes of Pashkám, and which are doubtless part of the same series. This band may be traced along the southern border of the trap as far as Múlbeck. The rocks of this band are much mixed up with trap, and in many places within the trap area masses of altered sedimentary rocks are met with, which are probably fragments of the Tertiaries which once extended continuously over this area, but which have been broken up and altered by the subsequent intrusion of the trap. From Shargol the southern boundary of the trap runs a little to the north of Múlbeck, and thence north of the Kashmir and Ladák road. At and near Báma-Yuru, the trap is much mixed up with Palæozoic rocks which I shall refer to subsequently; east of the last-named village the southern boundary runs north of the village of Wanla, and thence on the north of the stream flowing from the Choki-Lá. From Pashkám the northern boundary runs for some miles in an easterly direction, then bends to the south-east till it touches the Indus at Khalchi, from which point it again leaves that river and forms the summits of the high range on the left bank, gradually dying out among the sedimentaries to the west of the Zánkár river.

The trap throughout this series consists of fine-grained anamesites, green-stones, basalts, and serpentines, with occasional amygdaloids; it is never porphyritic, and when worn into pebbles acquires a brown-black glaze like the darker varieties of hæmatite.

I have already said that these traps die out a little to the west of the Zánkár river, in consequence of which the main mass of the sedimentary Tertiaries comes into direct contact with the Carboniferous rocks, which form the zone to the south of the Eocenes. Between Kio and the Zánkár river, the Eocenes, with a low northerly dip, rest upon and overlap the Carboniferous rocks, masses of the latter often protruding through the former, showing that we have another natural boundary, indicating the original southerly limit of the Eocene series.

In the Zánkár river, during its course through the Tertiaries, there were found, during the summer of 1878, large masses of pure native copper which had

been washed from the neighbouring rocks. The copper occurred in irregular nodules of many pounds weight. I could not discover the copper *in situ*, and cannot therefore say positively whether it was derived from the Tertiaries or from the older rocks further south.¹

To the south-east of Kio the Tertiary boundary runs near the right bank of the Markha river, crosses the Ladák and Kulu road at Látho, thence continues along the left bank of the Indus towards the Chinese frontier. The coarse conglomerates that form the highest beds of the series between Kio and Látho may be traced far to the east of the latter place. On the Markha river between those two places, masses of trap occur on the southern border of the Eocenes. This trap is of a highly crystalline structure, and not like the compact greenstones and serpentines of Shargol.

The line of occurrence of this trap is generally near the junction of the Palæozoics and the sedimentary Tertiaries, as is well seen near Gía, where the trap has clearly intruded among the Palæozoic limestone, which is here full of *Encrinites*.

On the Markha river and to the south-east of Gía, numerous trap-pebbles are included in the upper Tertiary conglomerate; but it is not clear that these pebbles belong to the same mass of trap as the one on this line.

The large mass of trap on the upper Indus above Leh forms a ridge-shaped mass, extending between the sedimentary Tertiaries to the north and the gneiss of Rupsu to the south. The upper Tertiary conglomerate near Gía and to the eastward contains pebbles of trap, of crinoidal Carboniferous limestones, of Rupsu gneiss, and of the lower Tertiary rocks. South-east of Gía the band of Carboniferous rocks dies out, and the Tertiaries are in direct contact with the gneiss of Rupsu.

Along the whole of the southern border of the Tertiaries to the east of the Zánkár river, these rocks have been much disturbed, and are not unfrequently inverted; from the distinct occurrence of overlap here and there, it seems probable that this boundary, like the northern, indicates the original limit of the area in which the rocks were deposited: the trap has, however, probably disturbed the original relations of these rocks.

The occurrence of nummulites in the higher Eocene rocks proves that these beds are of marine origin. Many of the lower littoral beds, on the other hand, from their heterogeneous composition, and from the frequent occurrence of cross-bedding, appear to me very probably to be of fresh-water or brackish origin. In the lower beds near Kargil, Mr. Drew obtained some gastropods allied to *Melania*, and some bivalves which seem to me to be *Unio* and *Dreissena*, though Dr. Stoliczka² considered them as *Pholadomya* or *Panopæa*; if my interpretation be correct, it confirms the fresh water origin of these rocks, which is borne out by the occurrence of an *Estheria* near Leh.

The above facts lead, I think, to the conclusion that the nummulitic rocks of the upper Indus valley were deposited in a narrow arm of the sea (as was

¹ General Cunningham ("Ladák," p. 22) says that the name Zánkár (or more correctly Zángskár) means "white copper" or brass; and at p. 234 of the same work, he concludes from this meaning that copper must occur in that country, though he could not hear of it.

² Mem. of the Geol. Surv. of India, Vol. V, p. 348.

suggested by Dr. Stoliczka), the borders of which were rendered brackish by the influx of fresh water. Subsequently to the deposition of these rocks, the southern border of the western half of the zone was broken up by a large mass of basaltic trap which followed the normal strike of the Himalayan rocks, as being in all probability the line of least resistance. The Kailás range formed at a lower elevation the northern shore line of this gulf, while the southern shore line in all probability followed the northern boundary of the Palæozoics of the Zánskár basin, and of the trap of the upper Indus.

At the time of the deposition of the nummulitics, the upper Indus valley must have been a wide depression below the level of the sea, flanked on either side by land. Since the Eocene period this valley has been raised to an elevation of 10,500 feet above the sea-level below Leh, and it is in all probability owing to this elevation that the Tertiaries have obtained their present generally south-westerly dip. This elevation of the Tertiaries (together, of course, with the surrounding rocks) to the north-west of the Zánskár river, must have been so gradual and even as not to disturb the original relations of the rocks, and, judging from the southerly inclination of the Tertiaries, was probably of greater vertical extent on the northern than on the southern side of the Indus. To the south-east of the Zánskár river, where the Tertiaries attain the enormous elevation of 21,000 feet (as in Tok (Kanri) peak, opposite Leh), the disturbance which they have undergone is considerably greater than to the west (where their elevation is less), and their southern boundary is often faulted.

In the former area, however, these rocks do not seem to have undergone the puckerings and crummings to which the Palæozoics have been subjected, the movements causing which would seem to have taken place before the Eocene period. It seems not improbable, from the prevalence of the south-westerly dip in the Tertiaries, that their northern border was first elevated, and that to the east of the Zánskár river, the higher conglomerates were deposited in a narrow valley at the base of this newly elevated Tertiary land, which was then rapidly undergoing denudation.

I am thus led to the belief that the great contortion which the pre-Tertiary rocks of Ladák have undergone took place in great part, at all events, previously to the nummulitic period, and from the presence of Jurassic-Cretaceous rocks (and no newer secondaries) in Zánskár (see below), that this contortion and denudation took place in the later Cretaceous period when the country (except the Indus valley) first emerged from the sea, beneath which it has probably ever since been buried.¹ From his observations in the Sub-Himalayan region, Mr. Medlicott² came to the conclusion that the contortion of the older rocks there took place after the Nummulitic period, and he pointed out the importance of comparing this relation with that in the Central Himalaya, where a different condition might prevail.

¹ Against this view there is the apparent parallelism between the Tertiaries and Carboniferous on the Gía river, which would indicate, if rightly interpreted, that here the great part of the disturbance was of post-Tertiary age. This is borne out by the greater amount of metamorphism and contortion which the Tertiaries to the south-east of the Zánskár river have undergone in comparison with those to the north-west.

² See "Manual of Geology, India," p. 684.

The Indus valley Nummulitics seem to indicate that the enormous elevation of the Central Himalaya did not take place at all events till post-Eocene times, while the elevation and contortions of the outer Siwaliks render it probable that the elevation of the whole Himalaya has occurred in great part since the period of the older Pliocene.

It may not improbably be, that in the Ladák Himalaya, lateral crushing had taken place before the Eocene, and brought the pre-Eocene rocks approximately into their present positions, during which a great smashing and crushing of these rocks must have taken place; the pre-Eocene rocks were then denuded. During the deposition of the Ladak Eocenes there was a pause in the lateral crushing action succeeded by another period of lateral crushing; this second crushing must have raised the Ladák mountains to their present height, during which elevation the Tertiaries were not so much smashed up as the lower rocks during the first crushing, but were, so to speak, carried up on the top of them. The post-Eocene period of lateral crushing was also probably post-Pliocene, and was the one which also crushed up the Siwaliks. These latter rocks with their underlying Nummulitics, being on the boundaries of the central elevated mass, would necessarily undergo much more crushing and smashing than the Eocene rocks of Leh, which, as I have said, might be carried up by the lateral movement on the top of the denuded older rocks with but comparatively little crushing.

Older Rocks.

I now come to the consideration of the pre-Tertiary rocks of the area under discussion, and commence my survey at the north-western end of the basin.

When treating of the slaty series of Drás, I have already shown that those rocks do not extend to the westward of a line running south-south-east about 16 miles to the east of the Kúrtse, where they are cut off by newer rocks. I have also shown that the Tertiary zone does not extend much to the south of either Shargol or Múlbeck, and a line running at first east and then south-east of the latter place. The rocks we have now to consider occupy the angle between the two lines, and extend far to the south-east into Spiti: a few of these rocks extend within the Tertiary area in the neighbourhood of Láma-Yuru.

Before going further, it may be well to mention that the rocks now to be noticed range from the Silurian to the Cretaceous, and that the great mass of those above the Carboniferous consist of the Triassic series. Most of these rocks were originally named by Dr. Stoliczka in the Spiti district, where they are all fossiliferous, and their divisions are tabulated on pp. 135 and *seq.* of his above quoted memoir. The strata above the Carboniferous (Kuling) were divided into upper Trias (Lilang), Rhatic (Para limestone), upper Rhatic or Lower Lias (Lower Tagling), and various higher groups of Jurassic and Cretaceous age. In most of the country examined by me where supra-Carboniferous mesozoic rocks occur, I have only here and there been able to identify the separate groups of Stoliczka, which all form part of one great rock-series, easily recognised by the great prevalence of limestones and dolomites. I have not been able to color these different groups separately in the map, and they are, therefore, all embraced in the large area colored sienna in the map, which must, accordingly,

be understood to comprehend strata ranging throughout the upper Trias (under which I include Rhætic) to strata of lower Liassic or upper Rhætic (lower Tagling) age. As I shall notice, there may possibly be some even newer strata included here and there in the area, though in the absence of fossil evidence I cannot be certain. Whenever I have been able to recognise any of Stoliczka's minor divisions I have mentioned them. It may be observed that in his second paper on Western Tibet, Dr. Stoliczka was disposed to unite the Trias and Rhætic¹

I commence my examination of the pre-Tertiary rocks of the Zânskâr basin at its north-western extremity.

To the south and south-east of Shargol (Sbergol), to quote the words of Dr. Stoliczka,² "the higher hills all consist of Triassic limestone, alternating near the base with rather highly metamorphic, and sometimes strongly carbonaceous shales, which it is very difficult to distinguish from the Tertiary beds," which I have already shown to occur to the north of and at Shargol. Dr. Stoliczka goes on to say that the determination of the Triassic limestone is tolerably certain, and that it is the same as that which occurs above Drás. The latter was considered by Stoliczka³ as the representative of the Keuper (Lilang) in its lower part, and apparently of the Para limestone in its upper and more dolomitic part. We shall subsequently see that the Shargol limestone underlies other dolomitic strata which are probably the representative of the Para, the Shargol limestone being the Lilang.

It does not appear that Dr. Stoliczka found any fossils in the Shargol limestone: in the stream running to that place from the south there, however, occur numerous blocks of a blue limestone full of a species of a large *Megalodon*, though I did not find the fossil *in situ*. These fossils seem to differ from *Megalodon triquetus*,⁴ characteristic of the Para limestone, by the larger size of the umbones, and by the deeper groove between the two valves. To Dr. Feismantel and myself the species appears to be indistinguishable from *Megalodon gryphoides* of Gûmbel,⁵ characteristic of the European Keuper. We have, therefore, pretty fair evidence that the Shargol limestone is upper Trias.

Dr. Stoliczka, in the notes of the Yarkand journey, goes on to say that the Triassic limestone can be traced to the south of Kârbu (Kharbu) and the Fotu-Lá; and he further observes, that this limestone near Kârbu and on the Fotu-Lá is underlaid by shales, which he classes as Carboniferous, and which he traced as far as Lâma-Yuru. These shales are generally carbonaceous and weather to a peculiar light brown color, and as they underlie the upper Triassic Shargol limestone, they may in all probability be classed as Carboniferous, since according to Stoliczka,⁶ the Lilang (upper Triassic) series in Spiti overlies (with here and there unconformity) the Kuling (Carboniferous) series; the Permian and Lower

¹ Mem. Geol. Surv. India, Vol. V, p. 352.

² "Scientific Results of Second Yarkand Expedition," Geology, p. 13.

³ Mem. Geol. Surv. India, Vol. V, p. 349.

⁴ "Manual of Geology of India," Pl. II, figs. 8, 8a.

⁵ "Sitzungsb. d. k. Akad. Wien.," Vol. XLV, p. 372, and figure.

⁶ Mem. Geol. Surv. India, Vol. V, p. 64.

Trias (Muschelkalk and Bunter) being absent. Subsequently, however, Stoliczka incidentally mentions¹ shales of lower Triassic age in Rupsu, and it may possibly be therefore that the Shargol shales (as I shall frequently style these rocks) are partly of lower Triassic age. As, however, they are unfossiliferous, and as more to the south, they overlie metamorphic Silurians, there is little doubt, both in Stoliczka's and my own opinion, that they are mainly Carboniferous, and they have accordingly been so colored in the map.

Dr. Stoliczka, as I have said, mentions the difficulty which he found in distinguishing the Tertiary from the Carboniferous shales, and it is not quite clear to me to which group he referred some shales to the east of Shargol, which I think are certainly the Carboniferous; he speaks of "lumps and patches of it (Trias limestone) sticking out of the *so-called* Tertiary shales," as if he thought, as I think, that the shales were not Tertiary. I incline to think that the limestone in these shales is mainly in the form of lenticular masses, interstratified with them, though some of them may be outlying masses of the Trias overlying the shales.

Before discussing further the south-easterly extension of the Shargol shales, I proceed to notice two sections taken from the northern border of these shales to the south. The first of these extends from the Kashmír and Ladák road near Múlbeck up the ravine known as Múlbeck Rúng. Leaving the Kargil river, we first cross the blue limestone corresponding to the Shargol *Megalodon* beds, which has a southerly dip. These rocks are succeeded for a distance of about 3 miles by alternations of hard and massive white, green, and purple slates, with sandstones and limestones, the whole series being much folded, and its thickness difficult to estimate; these slaty rocks are much like those of the Trias of Tilel.² The slaty rocks seem to be succeeded by a great thickness of nearly horizontal strata of white dolomites and blue limestones, like those occurring in a similar position in Tilel, as described in my paper quoted above, and apparently corresponding to the higher part of the Trias of Drás (Para limestone); the slates between the *Megalodon* beds and the dolomites being much thicker than the intermediate (limestone and shale) beds at Drás. The dolomitic rocks continue across the ridge at the head of Múlbeck Rúng in a rolling series to the north of Gonpa Láma Serai, where they were noticed by Stoliczka (Rangdum Gonpa),³ and are apparently faulted against the Silurians of the Drás series. Stoliczka merely noticed these strata from a distance, but speaks of them as "secondary deposits, undoubtedly of different formations." As I have said, I think, their highest beds are the topmost Trias (Para), and the series is undoubtedly the same as that which I have included in the Trias in Tilel and the Zoji-Lá.

The second section runs southward from the village of Hiniskot, on the Kashmír and Ladák road, across the Kangi-Lá. At Hiniskot itself we find cliffs of nearly vertical blue and buff limestones, corresponding to the Shargol *Megalodon gryphoides* beds, with a few slaty beds; these rocks continue in a rolled and much bent series till within some 2 miles of the village of Kangi, where we cross a synclinal axis in bright colored shaly slates, again underlaid by the

¹ Mem. Geol. Surv. India, Vol. V, p. 345.

² Rec. Geol. Surv. India, Vol. XII, p. 21.

³ Mem. Geol. Surv. India, Vol. V, p. 347.

lower limestones nearer and at the village. The limestones seem here to form an anticlinal, overlaid again to the south by the colored slates, with one thick band of soft and dark colored shales, containing large ferruginous concretions. Higher up the Kangi stream, we find the slates extending as far as the village of Ampaltan, where we find them gradually succeeded by blue limestones, and these again by buff dolomites. These dolomites continue in a rolling series across the Kangi-Lá to the Silurian slates of Rundum, where they were colored in an unpublished map of Stoliczka's as Trias. This section is not very clear; the beds on the north are, I think, certainly the Lilang, and the southern dolomite the Para limestone; if this be so and the section correct, the intermediate slates must also be part of the Trias; they resemble the similarly placed rocks of Tilel. The thin band of black crumbly shales at Kangi with concretions makes a curious approach in mineralogical structure to the Spiti shales as described by Stoliczka: the other rocks do not, however, agree with the other Spiti Jurassics.

It may be noticed that at and below the village of Kangi, there occur in the bed of the stream numerous pebbles of a crystalline trap, with a rust colored weathering; these pebbles have been derived from a mass of trap occurring on snowy peaks, D 24 and D 25, to the eastward, to which I shall have occasion to refer subsequently.

Returning to the Shargol Carboniferous shales, we find them continued, as we have seen from Dr. Stoliczka's notes, to the eastward along the line of the Kashmír and Ladák road: north of Kárbu a few small patches of Triassic slates and limestones are found resting on the shales, and the latter are a good deal mixed with the Tertiary serpentine trap, especially near the nummulitic zone: these shales were traced by Stoliczka and myself, as noticed above, to Lámá-Yuru. Crossing the stream at Kárbu and proceeding in a north-easterly direction, we find the Carboniferous shales underlaid by slaty rocks, green, red, and black in color, which form the summit of the ridge on which Nindam station is situated. Among these lower slates Dr. Stoliczka¹ recognised the green (Silurian) rock of Drás; these slates are much mixed up with the serpentine trap. At Lámá-Yuru the Carboniferous shales are underlaid by the same slate series as occurs near Kárbu, and some beds of sandstone, with a south-westerly dip. The same slate rocks mixed with ribband jaspideous rocks like those between Tilel and Drás, and with the slaty sandy (trappoid of Stoliczka) rocks of the Drás river and the Pangong lake, occur in a descending series in the gorge leading from Láma-Yuru to the Indus. These rocks are, however, so intimately mixed up with the Tertiary trap, that it is exceedingly difficult to map them with any accuracy. To the eastward I have traced these slaty rocks to the village of Wanla, where they again underlie the Shargol Carboniferous rocks. Dr. Stoliczka says¹ that the colored shales and slates underlying the brown carbonaceous (Carboniferous) shales of Láma-Yuru are the representatives of his Múth and Bhabeh series (upper and lower Silurian): he further thinks there are traces of syenite (central gneiss(?)) underlying these slates, though I did not observe them myself. Near the Indus the Silurian slates are cut off by the Tertiary trap. From the mineralogical composition of the rocks in the Láma-Yuru gorge, they

¹ *Geology, 2nd Yarkand Mission, p. 13.*

appear to me to be certainly the same as the slate series of Kashmír, Tilel, Drás, the Pangong Lake, and Cháng-Chenmo.

From the Fotú-Lá the Carboniferous band extends in a south-easterly direction, its northern boundary running through Wanla, and thence slightly north of the road across the Choki-Lá to the Zánkár river, where I shall take it up subsequently. The southern boundary runs near the village of Panjila, and thence in a south-easterly direction: near the village of Urcchi there is a small synclinal in the lower shale-series, occupied by a patch of the bright-colored Triassic slates and limestones. Near Wanla a large proportion of blue limestone occurs in the lower Carboniferous shales, which is not unfrequently crowded with *Enerinites*. Iron also occurs in these rocks, and is worked in small quantities. To the south-east of Wanla, the Carboniferous strata consist of black flaggy slates, which, however, weather to the usual light-brown color, by which character they are readily distinguished from the older Láma-Yuru slates, which always weather black.

Close to Wanla there occurs a wide dyke of the Tertiary trap running in among the Palæozoics, which requires a moment's notice. On the south side of this dyke, between it and the Carboniferous shales, there occurs a considerable thickness of coarse vertical conglomerate, a good deal altered by the trap, and containing pebbles of the Trias limestone, and of the crystalline trap, already noticed as forming peaks Nos. D. 24 and 25. I cannot say whether or no this conglomerate corresponds to the higher Tertiary conglomerate near Gía; but since it has been jammed in between the trap and the Palæozoics in vertical beds, it affords the important piece of evidence that it is older than the trap, and that consequently the crystalline trap within the Triassic area is older than, and was denuded at the time of, the formation of the basaltic trap of the Indus.

A section through the secondary rock-series from the village of Panjila, south of Láma-Yuru, to Yelchang bridge, on the Zánkár river, gives the following series of rocks. Leaving the shaly Carboniferous rocks near Panjila, we find the overlying Trias at first consisting of hard purple and green slates, which are nearly vertical, mixed with some calcareous and limestone bands: these are succeeded by softer and brighter-colored slates, like those of Kangi; while shortly below the village of Hanúpatta (Hunúpatta), we come upon blue limestones with a lower southerly dip. From Hanúpatta to the Sirsa Lá there is a succession of blue limestones and white dolomites, with a few slates, which form a rolling synclinal, the underlying poikilitic slates again appearing beneath the limestones at the pass itself.

These limestones and dolomites appear to me to be the Para limestones, and they contain sections of fossils which appear to be those of *Dicerocardium himalayense*, characteristic of this band. This being so, the underlying slaty rocks must be the Lilang series, the limestones of Shargol being represented by these slates; this section confirms the Triassic age of the rocks in the Kangi section.

From the Sirsa Lá to the village of Phatoksir and thence across the Shingi

(or Shingo, or Singhi) Lá¹ to Yelchang on the Zánkár river, there is a continuous succession of the same limestones and shales. For want of supplies I was unable to continue my journey beyond Yelchang, but Triassic (Para) dolomitic limestone extended as far as I could see up the Zánkár valley. According to Dr. Stoliczka² the Zánkár valley near Zangla consists on either side of contorted Triassic limestone (Lilang?) overlaid by the darker Para limestone on the higher ranges. To the south-east of Zangla near Niri-Sumdo (Niri-Chu), at the Shapadok-Lá, and the Saiji Lá, lower Tagling limestone (lower Lias) overlies the Para limestone; these are in turn overlaid by Spiti shales in small patches (the occurrence of the latter is roughly indicated on the map by yellow patches, while the lower Tagling is included in the sienna). I have no doubt but that the Trias of Yelchang is continuous with that of Zangla, with patches of Jurassic rocks occurring on the higher hills. I may observe that to one who like myself did not give the local names to the different limestones of the great Trias-Jura of this district (for, as in America, the Trias and Jura are one great rock series), it is exceedingly difficult to recognise these palæontologically different but mineralogically very similar limestones. General Cunningham³ observes that limestones are found continuously across Zánkár from the Shinghi-Lá to the Láchi-Long-Lá, on the Ladák and Kulu road, where, as will be noticed below, the Trias seems to continue across Zánkár. I therefore conclude that the Triassic and lower Jurassic rocks form, with small exceptions, the whole of the central part of the great limestone ellipse of Zánkár.

Near the village of Thonde, in Zánkár, Dr. Stoliczka says⁴ that "the Triassic beds are separated from the Silurian sandstones by a dark band of a greenstone-like rock, which I presume to be Carboniferous." These latter rocks have been provisionally so colored on the map, as there is a strong presumption from their position that they are rightly referred to that formation.

The trap occurring on peaks D. 24 and 25 must be post-Triassic age, though, from the amount of snow, I could not examine it closely *in situ*. It is distinguished from the Shargol trap by its more crystalline structure, and by the peculiar rusty brown weathering.

Reverting once again to the presumed Carboniferous rocks, which we have already traced as far as the village of Wanla, we find that from this point they continue across the Choki-Lá down to the Zánkár river, near the village of Chiling; thence their northern boundary is continuous with the southern boundary of the Tertiaries, which we have already traced. From Wanla to a

¹ Dr. Thomson is said to have brought nummulites from this pass (Mem. Geol. Surv. of India Vol. V, p. 354); this seems to have arisen from confusing this pass with the one to the north-east of the village of Shingo near Kio, which is often called Shinghi-La, and under which name Dr. Stoliczka alludes to it when he found nummulites on it (sup. cit., p. 344); it is rather strange that the similarity of the two names did not strike Dr. Stoliczka when he wrote his paper. This error is repeated on page 14 of the Geology of the Second Yarkand Mission. Mr. Medlicott (Man. Geol. of India, p. 644) pointed out the probable error.

² Mem., Geol. Surv. of India, Vol. V, p. 246.

³ "Ladak," p. 57.

⁴ Mem., Geol. Surv. of India, Vol. V, p. 346.

long distance up the Markha river these rocks have a general south-westerly dip, and form a band of very uniform breadth to the north of the Trias. Near Kio, the lowest beds of the Carboniferous series which are exposed, are nearly vertical, and consist of blue-black limestone, traversed by veins of yellow quartz. Nearer Kio itself, the south-westerly dip becomes flatter, and the limestone is overlaid by brown shales and blue slates, with many bands of white and yellow quartz: many of the slates contain bands of carbonaceous matter, and are not unfrequently studded with small crystals of pyrite.¹ On the Markha river, a little below Kio, the yellow quartz is in great force, and gold-washing is carried on to a considerable extent in the detritus from these quartz-reefs. At Kio and in the neighbourhood, stems of *Encrinites* are of very common occurrence in the Carboniferous limestones, and at that place I obtained a coral closely allied to *Cyathophyl-lum*. To the south-east of Kio the mineralogical composition of the presumed Carboniferous rocks has the same general characters as those described above; the relative development of the limestones and shales is, however, locally very variable.

In noticing these rocks at Kio, Dr. Stoliczka observes:² "The nummulitic rocks are suddenly replaced by slates and carbonaceous limestones full of crinoid stems, which appear to be of Carboniferous age. All the way up from Kew (Kio) to the head of the Markha valley, nothing but these carbonaceous crumbly slates occur." No fossils were found in these rocks, and Dr. Stoliczka adds that there were probably representatives of the Silurian and Carboniferous among them. The slates of Kio are frequently full of small cubical crystals of pyrite. To the north-west, as we have seen, these rocks are continuous with the Shargol shales which we have classed as Carboniferous. To the south-west of Tso Moriri, I have traced this band into a series of slates noticed by Dr. Stoliczka,³ who observes that "these slates can only belong to the Kúling (Carboniferous) series, being perfectly identical with the rocks of this (series) in mineralogical characters and geological position, underlying the Lilang limestone."

There is, therefore, every presumption of the whole of the blue bands on the map being of Carboniferous age.

To the south-east of the valley of the Markha river the band of Carboniferous rocks continues along the southern border of the Eocenes, till it finally dies out on the upper Indus, between the latter and the gneiss of Rupsu. On the Gía river the Carboniferous rocks have undergone great contortions; they consist at Gía itself of brown weathering shales mixed with blue quartzitic limestones generally in lenticular masses; the shales are often quartzitic and carbonaceous and dip generally towards the Tertiaries, which they frequently much resemble.

To the southward of Gía we have at first a folded series of these rocks, which, further to the south, is underlaid by hard blue slates and micaceous sandstones, similar in structure and position to the Silurians of Láma-Yuru. Near

¹ The composition of the Carboniferous series here is closely analogous to that of the Kial series in the outer hills, which confirms my opinion as to the Carboniferous age of the latter (see Rec. Geol. Surv. of India, Vol. IX, p. 160).

² Mem. Geol. Surv. India, Vol. V, p. 314.

³ *Ibid.*, p. 343.

the Tagalúng-Lá and to the west of Balla St. there occurs a synclinal in these rocks, consisting of the Carboniferous shales, quartz and limestones; near the pass large lenticular masses of pure white saccharoid quartzite, like that of the Pangong Lake, occur in these rocks. In the centre of this synclinal there occur beds of dolomitic limestones, mixed with some reddish shales, which are probably the Lilang series. Dr. Stoliczka, in his notes on the Tagalúng-Lá¹ (Taglang), does not notice these limestone rocks, and speaks of all the rocks as belonging to the metamorphic series.

The Carboniferous rocks in the Tagalung synclinal are underlaid to the south by the slaty and sandy Silurians. Lower down the Zára river there is an anticlinal, to the south of which the slates gradually assume a gneissoid character, the crystalline rocks occurring as lenticular masses among the slates.

This gneiss and slates are again overlaid conformably to the south-west by the carboniferous rocks of Kio. The gneiss and slate series can be traced to the north-west nearly to the Markha river, where they form a wedge-shaped mass intruding between the Carboniferous rocks, which here split to receive them. To the south-east the slates and gneiss, which form one series, have been traced by Dr. Stoliczka to the south of the Indus, and across Rupsu to the south of Tso Moriri and were classed by him as the equivalents of the Silurian. The gneiss is dark-colored, and very generally porphyritic, with large crystals, often 3 or 4 inches in length, of gray orthoclase. It is quite different in character from the white gneiss of the Kailás range, and when non-porphyritic is very like the altered Silurians of Tánkse. As the Rupsu slates and gneiss directly underlie strata which are certainly not newer than Carboniferous they must probably be of Silurian age, as suggested by Dr. Stoliczka, and consequently the equivalents of the slates of Drás and Tánkse. It will be noticed that the strike of the altered Rupsu Silurians is continuous with that of the unaltered Silurians of Láma Yuru, and the two probably belong to the same band.

To the south-west of the Silurians of Rupsu the Carboniferous rocks, which, as we have seen, split near the head of the Markha river, form a continuous band of nearly the same width, which I have traced to the south-east of the Kiang-Chú plain, whence the same band has been traced by Dr. Stoliczka in a southeasterly and southerly direction into Spiti, and which, as before said, to the south-west of Tso Moriri, underlies the Lilang limestone.

At Kiang-Chú the Carboniferous rocks consist of shales, frequently containing crystals of pyrite, like those of Kio, and alternating with large lenticular masses of blue quartziferous limestones; these are succeeded by banded limestones, alternating with highly carbonaceous shales. These shales continue for some distance in a V-shaped hollow up the valley leading to the Láchi-Long Lá; they are succeeded by blue, buff, and white limestones and dolomites which, with the occasional exceptions of small patches of carboniferous shales appearing beneath them in the valleys, continue to near Lingti. Near the top of the Láchi-Long pass there seems to be an anticlinal of Carboniferous shales underlying the dolomites. In these limestones and dolomites there are seen numerous sections of *Megulodon*

¹ Mem. Geol. Surv. India, Vol. V., p. 343.

and *Dicerocardium*, and most of the rocks may be taken as the equivalents both of the Lilang and Para limestones:¹ fragments of a *Lima* are not uncommon; and corals and crinoids are extremely common in these rocks. The thickness of this dolomitic series is at least 3,000 feet near the Láchi-La. In the Lingti valley the Para limestone with *Dicerocardium* occupies the upper part of the hills, underlaid by the Lilang limestone; the rocks have here undergone immense contortions and foldings. To the south-west of Lingti the Triassic rocks are underlaid by blue and reddish shales, with white quartzites and blue limestones: from their position and composition I have little doubt but that they are mainly Carboniferous; patches of similar rocks, with *Productus* and *Spirifer*, were noticed by Dr. Stoliczka² to the south-east of Lingti (Tsárap valley), underlying the Lilang limestone near Lámaguru (Yuroo. Stoliczka). I have traced the Carboniferous and Triassic rocks a considerable distance to the north-west of Lingti, and they are doubtless continuous with the corresponding rocks near Zangla, mapped by Dr. Stoliczka, overlying the Silurians of Padam.

To the south-east of Lingti, Dr. Stoliczka³ observes that above the Lilang limestone at the bottom of the valley, the greater part of the Tsárap valley consists of the Para limestone full of *Dicerocardium himalayense* and *Megalodon teiqueter*. The Para limestone in this district is of a light-blue color, with a marbling of white; it is very different from the white dolomites of the Drás river, which Dr. Stoliczka correlates with it; the Triassic rocks, however, appear to me to vary very considerably in composition. In the upper part of the Tsárap valley, according to Dr. Stoliczka, the higher hills consist of the lower Tagling limestone (lower Lias?) with *Terebratulæ* and *Rhynchonellæ*: the summit of the Pangpo-Lá consists also of the same limestone, while the higher ridges near the pass are capped with Spiti shales, and Gienmal sandstones (upper Jurassic); and fragments of the Chikkim (Cretaceous) limestone were also found in the neighbourhood; these rocks must apparently rest unconformably on the lower Tagling. To the north of the Pangpo-Lá the lower Tagling limestone, according to the same authority, forms the prevailing rock, underlaid for a short distance by the Para limestone, which appears to be greatly developed to the south-east. Near Khiang-Shisha the limestone belongs chiefly to the Lilang group, and

¹ There may probably be representatives of the lower Lias (lower Tagling) on some of the higher hills. On page 38 of volume XXII of the Quarterly Journal of the Geological Society, Mr. Davidson in describing some fossils collected by Colonel (then Captain) Godwin-Austen, mentions some Brachiopods, said to have been obtained in a light gray limestone "near Lacholung-Lá, north side, in the Suru country in Thibet." In Suru there is no Lacholung-La that I am aware of, and I think the place referred to must be the Lachi-Long Lá in Rupsu. The said fossils are either Jurassic or Cretaceous, and if the above determination of locality be correct, rocks of one or other of these systems must occur probably on the higher peaks around the Lachi-Long. The crest of the pass shows carbonaceous shales in an anticlinal which I think are certainly Carboniferous, and undoubted Trias rocks with *Megalodon* occur near by. If the patches of newer rocks exist near the pass, they would be on the strike of similar rocks noticed by Stoliczka on the heights above the Pangpo Lá.

² Mem. Geo. Surv. of India, Vol. V, p. 342.

³ *Ibid.*—I was prevented by want of supplies from examining this country more closely.

is underlaid to the north-east, as noticed above, by the Carboniferous series, which again overlies the metamorphic Silurians of Rupsu.

In the map accompanying this paper the whole of the great limestone series above the Carboniferous, from the Lilang to the lower Tagling limestone, is colored of one tint, and may be called the Trias-Jura. Owing to the variations in the mineralogical characters of these rocks, to the general absence of fossils, to the enormous contortions which the rocks have undergone, and lastly, but not leastly, owing to the difficult nature of the ground, and the short time that one can spend in these inhospitable regions, it would be quite impossible to map the different outcrops of each of the separate groups. Near Lingti the rocks, which I consider as the Carboniferous, are underlaid by a great thickness of hard dark slates, quartzites, sandstones, jaspideous rocks, and the slaty-sandy trappoid rock of the Drás river. These rocks which may be traced across the Báralácha pass into Lahúl, I have also traced to the north-west into the Silurians of Padam and Zangla which rest upon the gneiss of the Zánskár range, and continue thence to join the slaty rocks of Drás, to the south-east these rocks are continuous with the fossiliferous Silurians of the Bhabeh pass and Múth.

Speaking of the great slate series at Lingti, Dr. Stoliczka observes¹, "Any one acquainted with the rocks of the Múth series in the Pín valley would find all these represented here," and speaks of the lower beds as corresponding with his Bhabeh group (lower Silurian).

Near Lingti the rocks are very horizontal, and the summits of the ranges are capped by shales, blue limestones, and white and purple quartzites and sandstones. Some of these limestones and sandstones seem to me to be probably of Carboniferous age, as they correspond to similar rocks at Pángong, and also to rock specimens in the Indian Museum from the Carboniferous series near Múth: the lower beds are probably, however, upper Silurian, since Dr. Stoliczka found a fragment of an *Orthis* in similar rocks to the west of the Báralácha (Baralatse) pass. The upper Silurians and Carboniferous (Múth and Kuling) in this district and Spiti (as I judge from rock-specimens in the Indian Museum collected by Dr. Stoliczka) seem frequently to be very similar in mineral composition, and it requires a full series of fossils to separate them distinctly. The blue patches on the map in this district must be considered as only approximately of Carboniferous age, they mainly serve to indicate the distribution of the light-colored quartzites and shales on the top of the older slates.

On the Bhága river, some miles below the village of Dárcha,² the Silurian slate series is underlaid conformably by distinctly stratified granitoid gneiss³ which Dr. Stoliczka recognised as his so-called "central gneiss," and which, he says, underlies undoubted Silurians.

This gneiss forms the southern limit of the Ladák and Zánskár basin, but may be treated of here. To the north-west this gneiss is continuous, with the great mass of gneiss of the Zánskár range and Suru, which I described in a

¹ Mem. Geol. Surv. of India, Vol. V, p. 341.

² For this area see my map published in the eleventh volume of the "Records," p. 85.

³ In a previous paper (Rec. Geol. Surv. India, Vol. XI, p. 55) following Dr. Stoliczka, this gneiss was stated to occur at Dárcha itself.

former paper,¹ but which I could not then certainly determine to be the "central" gneiss; according to Stoliczka's identification, this gneiss may now be considered as of pre-Silurian age, and in this district as having been altered out of an older and conformable slate-series, unless some hidden unconformity should exist.

The rocks on the southern flanks of this gneiss ridge will be treated of in the next section, and their general relations in the last section.

IV.—ROCKS OF SOUTH LAHÚL AND KULU.

To the south of the gneiss ridge of Lahúl, we find an ascending series of slates, with a general south-westerly dip. Near the junction of the Chandra and Bhága rivers, we find blue limestones, with carbonaceous shales and a few pale sandstones, capping the slates in the angle between the two rivers. To the south a large mass of the same limestone and other rocks overlies the slates with a southerly dip, and appears to be itself again overlaid by the same slates. The limestones, on a more careful examination, are, however, seen to be folded back on themselves, and it appears probable that they form a synclinal, the slates on the southern side of the synclinal having been bent over and inverted on the limestones: from their physical characters there can be no doubt but that these limestones are the same as the limestones of North Lahúl,² which are probably partly upper Silurian and partly Carboniferous.

The Silurian slates of the Bhága and Chandra rivers I have previously traced³ into Pángi to the north-west, and for some distance to the south-east. Near the village of Kokser on the Chandra there occurs, at the base of an anticlinal in the slate series, some very massive gneiss, which, I think, is in all probability the same as the central gneiss of North Lahúl. This gneiss is overlaid by alternations of gneiss, micaceous rocks and slates, most of which appear to pass directly into the slates underlying the higher limestone, and which would, therefore, seem to be altered Silurians. These rocks continue across the Rotang pass and down the Beás valley nearly to the town of Naggar. Some of the gneiss is very massive, and in many cases seems to overlie the slate-series; this, however, may be due to inversion, and it seems to me probable that some of this gneiss is "central" gneiss, while some has almost certainly been altered out of the overlying Silurian slates. The series is, however, so involved that I was not able to mark out any bands as of a fixed position.

To the south of Naggar we have generally slates and sandstones till we reach the infra-Krol and Krol groups of Mr. Medlicott near Bajoura, which have been already described by him,⁴ and to which I shall, therefore, not refer on the present occasion.

¹ Rec. Geol. Surv. India, Vol. XI, p. 53.

² In a former paper (Rec. Geol. Surv. India, Vol. XI, p. 54) I thought from their apparently lying among the slates that these limestones formed part of the lower Silurian series.

³ Rec. Geol. Surv. India, Vol. XI, p. 55.

⁴ "Mem. Geol. Surv. India, Vol. III, pt. 2, p. 57.

V.—SUMMARY AND GENERAL CONCLUSIONS.

I now proceed to bring to notice some considerations regarding the general relations of the Ladák rocks to the rocks of the neighbouring Himalaya. In so doing I shall take the rocks in their geological sequence.

1. *The Tertiaries*.—These rocks have been sufficiently treated of in the section devoted to them. I have only to bring to notice the very remarkable resemblance in mineralogical character which exists between these rocks and the corresponding Eocene (Subáthlu) rocks of the outer Himalaya. We have good reason to believe that these two groups of rocks were deposited in perfectly distinct basins, and we can, therefore, only conclude that this resemblance in mineralogical characters is due to the Eocenes of both regions having been deposited under very similar physical conditions, and to their materials having been derived from the disintegration of very similar rocks.¹

2. *The Cretaceous*.—As only small patches of cretaceous rocks occur in the area under consideration, which I have not seen myself, I have no remarks to make concerning them.

3. *The Trias-Jura and Carboniferous*.—The Triassic and Jurassic rocks, with which the Carboniferous are often closely associated, in this area of the Himalaya occupy three main elliptical basins, viz., that of Drás and Tilel, that of Zánkár and Ladák, and that of Kashmír proper, while other outlying masses of the same rocks occur in the Cháng-Chenmo valley, and probably (though the correlation is not certain) in the outer hills. In the western part of the area the Trias and the Carboniferous seem to be very closely connected with each other, and (especially in Kashmír) it is frequently very difficult to distinguish between the two, and, as I have said in my last paper, some of the rocks mapped as Carboniferous may really be Trias, although as the upper beds are unfossiliferous, and of the same mineral character as the lower, except occasionally, it is difficult to distinguish them. No traces of the Jurassic rocks have been noticed in Kashmír or Tilel.

In the Zánkár and Ladák basin, the Carboniferous is very distinct from the Trias, and according to Dr. Stoliczka, there is sometimes local unconformity between the former and the upper groups of the latter: it may be that the lower Trias is represented in Kashmír and Tilel, which would cause the greater union of the Carboniferous and Trias in those districts.

In Spiti Jurassic rocks are extremely prevalent, while, as far as I can judge, they appear to become less and less developed as we approach the north-western extremity of the Zánkár and Ladák basin; Cretaceous rocks are also well developed at the south-eastern extremity of this basin, and are represented only by patches here and there towards the central part. It would thus appear that in the north-western portion of our area the rocks of these basins are older than many of those to the south-east, there being a gradual increase in the proportion of Trias, Jura, and Cretaceous as we travel from Kashmír to Spiti.

The Trias-Jura in these basins is generally characterised by the great pre-

¹ It may possibly be that the Indus and outer Himalayan Eocenes were deposited in two arms of a sea connecting the two to the westward.

valence of whitish dolomites and dolomitic limestones, often locally alternating with poikilitic shales and slates, the relative development of which varies considerably in different districts. The Zoji-Lá slates¹ still remain a puzzle to me, as I cannot correlate them with any of the Ladák rocks, though I still think those nearest the Trias are newer than it, from the evidence of the Panjtarri section. Some of the metamorphic rocks in the centre of the ellipse must, however, I think, be older, though it is extremely puzzling to imagine how they are related to the other rocks, and the country is so rugged and difficult of access that it will be very hard to come to any precise conclusion.

In most parts of Zánskár, Ladák, and Tilel the rocks above the Carboniferous form one continuous geological series, characterised by the great prevalence of dolomites and limestones; except towards Spiti, fossils are very rare, and the whole naturally presents a combined Trias-Jura, as in America. Had no fossils been found in any of these strata, and were geological nomenclature to have originated in this district, the whole rock-series would be classed as one great system.

The great geological unity in many districts of the whole series, from the Carboniferous to the Jura, is a point on which I desire to lay great stress, as indicating the different results arrived at by purely stratigraphical, on the one hand and purely palæontological geology, on the other.

The Carboniferous rocks vary considerably in mineralogical composition: in many parts of the valley of Kashmír they consist of pure blue limestones, full of characteristic fossils; while in other districts of Kashmír and elsewhere, they consist mainly of alternations of shales, slates, and limestones, very frequently containing crinoids and carbonaceous matter, and at other times quite unfossiliferous.

From the occurrence of the Carboniferous and Triassic series generally in synclinal ellipses, with their longer axes coincident with the normal strike of the Himalayan rocks, together with the generally uniform mineralogical character of the Trias, I think it almost certain that these rocks once extended continuously over the whole area.² It may be that from the varying composition of the Carboniferous series these rocks were deposited in a shallower sea than those of the Trias.

From the occurrence of no rocks newer than the Cretaceous, and from the vast amount of denudation which must have taken place to remove the Jura and Trias from such large areas, I am greatly inclined to believe that, with the exception of the Indus valley and a band along the outer hills, this area has been land continuously since the Cretaceous epoch.

During the past season I have for the first time had an opportunity of seeing the Krol limestone, and desire to add a few words to my previous conclusions regarding it. It will be remembered that I have described a band of limestone and other rocks running along the outer foot of the Pír Panjál range³ under

¹ Rec. Geol. Surv. India, Vol. XII, p. 17.

² I desire to retract an opinion previously expressed (Rec. Geol. Surv. India, Vol. XI, p. 48) that the Carboniferous rocks were deposited in separate basins.

³ Rec. Geol. Surv. India, Vol. IX, p. 160.

the name of the Krol series, which I have regarded as the representative of the Carboniferous. This limestone band I have also considered to be almost certainly, from its composition and position, to be the equivalent of the inverted band of Krol limestone running along the foot of the lower Himalaya in the Simla district, and these opinions I still hold to.

I at the same time considered that the whole of the limestones capping the slates in the Simla district, which are presumed to be the same as the Krol of the foot of the mountains, to be also of Carboniferous age. An inspection of these Simla limestones, with their underlying Blaini rocks and Simla slates, has shown me that they agree so closely with the Carboniferous and Silurians of Lahúl, that I am most strongly confirmed in my opinion that the slates are of Silurian, and at all events the lower limestones, of Carboniferous age. Mr. Medlicott,¹ in describing the infra-Krol rocks, notices in them the great prevalence of a carbonaceous element, and in the overlying Krol, of limestones underlain by quartzitic sandstones. In both these characters the rocks in question agree exactly with the presumably Carboniferous rocks of North Lahúl.

The Krol limestone is, however, so much thicker than the Carboniferous of Lahúl and Ladák, that I now incline to the opinion that the upper part of it is probably the representative of the Trias of those districts. The characteristic dolomite is, however, wanting, and in the absence of fossils we have no means of sub-dividing the Krol. I have already stated my opinion that the enormously thick limestones of Kashmír may be the representatives of both Carboniferous and Trias, and I now extend this opinion to the Simla Krol limestone and the Great limestone of the outer hills. In Kashmír, as I have noticed above, the Carboniferous and Triassic series are generally so closely related that it is often difficult to draw any hard and fast boundary between them, and since they often vary locally to a very considerable extent in mineralogical composition, there would be nothing extraordinary in their being still more indistinguishably blended together in a region some distance away. According to this view the infra-Krol carbonaceous shales would probably be Carboniferous (with which rocks in Ladák they correspond in composition to a considerable extent), and both upper and lower Trias and upper Carboniferous may be represented in the Krol. Some of the shales in the Krol are much like those of the infra-Krol.

4. *The Silurian*.—The past season's work has rendered an important contribution to the geology of this part of the Himalaya, in confirming the conclusions previously arrived at as to the Silurian age of the great slate series. The key to this problem lies in the Spiti district, where these slates contain Silurian fossils, and underlie conformably the Carbo-Triassic rock series, and overlie the "central" gneiss. From Spiti these Silurian slates may be traced through Zánkár to Drás and thence to Tilel,² where I have elsewhere shown that these slates are the equivalents of those of the Kashmír valley, the Pír Panjál and the Kishtwar district. The slates of Pángi,³ from their relations to the gneiss, must in all probability be of contemporaneous age.

¹ Manual of Geology of India, p. 600.

² Rec. Geol. Surv. India, Vol. XII, p. 20.

³ *Ibid.*, Vol. XI, p. 54.

The slates of Láma-Yuru, Tánkse, the Pangong Lake, and the Cháng-Chenmo valley, from their similarity in mineral composition to those of the Drás river are likewise inferred to be of the same age, which inference is strengthened by the slates of Pangong, which can be traced into connection with those of Tánkse, underlying strata of presumed Carboniferous age.

The slates and gneiss of Rupsu, which likewise underlie Carboniferous strata, must also be placed on the same horizon.

5. *The lower gneiss.*—In the foregoing sketch it has been shown that the gneiss of the Kailás range conformably underlies a large thickness of slates, which seem to correspond approximately in position to the Silurian: following the same system of nomenclature, such gneiss may be termed Cambrian gneiss as consisting of a distinct geological formation. It has further been shown on a previous occasion,¹ that the gneiss of the Zánkár range and of Kashmír is similarly situated in regard to the slates of those districts, which are also classed as Silurian; there is, therefore, considerable *prima facie* evidence that all this gneiss is contemporaneous.

It now remains to consider whether any or all of such gneiss is equivalent to the "central" gneiss of Dr. Stoliczka. It appears from the sections of the gneiss and Silurians in the Spiti district, where the "central gneiss" was first named, that that gneiss is unconformable to the Bhabeh Silurians, though this is not clearly stated in the text: if this be true, the central gneiss existed as such at the time of deposition of the slates. Dr. Stoliczka, however, himself recognised the gneiss of North Lahúl as "central gneiss,"² and also suggested that some of the gneiss of the Zánkár range to the south of Padam and Suru belonged to the same formation. No evidence of unconformity can be seen in this section.

It has been noticed in my paper on the gneiss of the Zánkár range³ that possibly some portion of the latter was gneiss at the time of the deposition of the Silurians; and it was suggested that such gneiss might be the equivalent of the "central gneiss." It was also shown on that hypothesis that the gneiss in North Lahúl identified by Dr. Stoliczka as "central gneiss," must, if rightly identified, be unconformable to the overlying Silurians. But until the conformity or unconformity of the central gneiss is elsewhere settled, it cannot be settled here.

It, therefore, seems pretty clear that the "central" gneiss is represented in the Zánkár range, but, as I have said in my above quoted paper, how much or how little of such gneiss is "central gneiss" cannot be determined. Similarly, in the Kailás range, it is probable, in my opinion, that the lower massive gneiss may be the central gneiss, and therefore unconformable to the higher gneiss beds, if the central gneiss is always so: how much or how little of the central gneiss occurs there I cannot possibly say. As in my other maps, the whole of the gneiss underlying the Silurian slate series has been colored the same tint, and has been called central gneiss; this gneiss must, however, include both the gneiss conformable and that unconformable to the slates (if there be such) and might rather have been called Cambrian and central gneiss.

¹ Rec. Geol. Surv. India, Vol. XI, p. 59.

² Mem. Geol. Surv. India, Vol. V, p. 341. Rec. Geol. Surv. India, Vol. XI, p. 59.

³ Rec. Geol. Surv. India, Vol. XI, p. 60.

The enormous thickness of slates overlying the gneiss in Pángi and in Cháng-Chenmo appears to me to be at least as thick as the slates in the Bhabeh section. It would, therefore, seem on the unconformity hypothesis that such gneiss as conformably underlies the Silurians, and which I call Cambrian gneiss, is unrepresented in that section. How thick or how thin this conformable Cambrian gneiss may be, or whether it is the same as the central gneiss, I cannot say. In other places, where the slate series is thinner, some of the great underlying gneiss series, as I have said in my previous papers, may correspond to part of the Silurians of the Bhabeh section.

I have already stated that the gneiss of the Kailás range dips to the north, and that the oldest beds are consequently exposed along the valley of the Indus: and I have also shown that when the Palæozoic rocks appear along the valley of the Indus beneath the Tertiaries that they are either of Carboniferous or upper Silurian age. We may, therefore, pretty safely conclude that the southern boundary of the Kailás gneiss is a faulted one.

Dr. Stoliczka did not apparently observe the relations of the gneiss of the Kailás range to the overlying slates, and, apparently identifying it with the gneiss of Rupsu, came to the conclusion that all the Ladák gneiss was of Silurian age, a view which in a previous paper¹ I accordingly adopted, before I had personally examined the relations of the rocks *in situ*. This view was, of course, adopted in the "Manual of the Geology of India".² With regard to the objection that the Ladák gneiss differs in composition from the central gneiss, I may state that I have elsewhere³ shown that the gneiss of Drás is frequently granitic in composition, and that there is also a great variety in the composition of the Ladák gneiss, granitic gneiss being not uncommon among the syenitic varieties. The presence of veins of albite granite in the gneiss of the Kailás range in the Chimray valley is another point, as far as it goes, connecting this gneiss with that to the south.

A general survey of the map from north to south shows a series of gneissic ridges (Dhaoladhar, Pir-Panjál, Zánskár, and Kailás) running from south-east to north-west, the hollows between which ridges are sometimes occupied by normally overlying Silurians, and sometimes by newer rocks, which have been faulted down.

ADDITIONAL OBSERVATIONS.

In conclusion, I may add, that I have lately found a series of Carboniferous fossils in the Indian Museum, which were sent by Mr. F. Drew, and were obtained in the Wardwan valley, a little above the village of Sūkness.⁴ These fossils comprehend the characteristic Carboniferous *Fenestellæ*, *Producti*, and *Spirifers*, and occur in a black shale like that of Eishmakám in the Lidar valley of Kashmír. Some dolomitic limestones, also sent by Mr. Drew from a point still higher up the Wardwan, appear to belong to the Trias.

¹ Rec. Geol. Surv. India, Vol. XI, p. 59.

² Page 653.

³ Rec. Geol. Surv. India, Vol. XII, p. 19.

⁴ See map and paper by myself in "Records," Vol. XI. Sūkness is about 16 miles north of Lushin.



Near Avantipúr in Kashmír, I found this season some Carboniferous fossils in the higher beds of the trappoid rocks, showing that some of these extend upwards into the Carboniferous.

TEETH OF FOSSIL FISHES FROM RAMRI ISLAND AND THE PUNJAB, *by* R. LYDEKKER,
B.A., *Geological Survey of India.*

DIODON.

Among the collection of fossils transferred to the Indian Museum from the Asiatic Society of Bengal, there occurs the palatal tooth of a fish, said to have been obtained from Rámri (Ramree) Island, off the Arakan Coast, by Captain Foley. This tooth consists of a series of horizontal and oval plates, lying one above another. Each plate is divided by a vertical line into symmetrical lateral portions, and the lowest plate seems to have lately separated from another inferior plate. Superiorly the tooth is bevelled away by an oblique and concave surface of detrition, exhibiting a section of the edges of each of the component plates. The longer diameter of the lowest plate is 1·2 inches, and the shorter 0·7 inch. The above description will clearly show that the tooth belongs to the genus *Diodon*.

A precisely similar tooth was obtained by Mr. Wood-Mason at Port Blair, in the Andamans, in a sandstone rock.

With regard to the age of the deposits from which these teeth were obtained, it appears from Mr. Mallet's paper on the "Mud Volcanoes of Rámri and Cheduba,"¹ that the author considers the Rámri rocks to be of Nummulitic age: Mr. Blanford, in the "Manual of the Geology of India,"² also classes most of the Rámri rocks as Nummulitic, but thinks that some on the eastern side of the island may be of cretaceous age. The rocks of Port Blair, according to Mr. Blanford,³ are similar to those of the Arakan Yoma, which (p. 713) are also Cretaceous and Nummulitic. From the majority of the rocks in Rámri Island being of Nummulitic age, and from *Diodon* not being known elsewhere below the Eocene, I think it most probable that the fossil teeth are of Nummulitic age.

The living Globe Fishes, according to Dr. Gray,⁴ are inhabitants of all the warmer seas, and comprise four species, of which *D. hystrix* alone inhabits the Indian Ocean. Of the latter species I have examined a small specimen, some 10 inches in length. In that specimen the teeth are, of course, much smaller than our fossil specimen, but as the living species grows to a very large size, no distinction can be drawn on these grounds. In *D. hystrix*, however, the worn surface of both upper and lower teeth is quite flat, while in the fossil

¹ Rec. Geol. Surv. of India, Vol. XI, p. 192.

² p. 717.

³ *loc. cit.*, p. 733.

⁴ Brit. Mus. Cat. of Fishes, Vol. VIII, p. 306.

tooth this surface is markedly concave. Owing to the difficulty of seeing the teeth in the jaw of *D. hystrix*, I could not institute any closer comparison. I have no opportunity of comparing the teeth of the three other living species with the fossil.

Of the fossil Diodons, *D. tenuispinus*, from the Eocene of Monte Bolca, is a small species,¹ while our fossil is a large one. *D. scilla*,² from the Tertiaries of Southern Italy, seems to have the edges of the plates of the teeth crenulated. The teeth of *D. erinaceus*³ seem to be unknown. The teeth of *D. vetus*, from America,⁴ seem to have had triangular plates. A *Diodon* has been mentioned by Professor L. Adams⁵ as occurring in the Miocene of Malta, but has not been specifically named.

Although I cannot be certain of the specific distinctness of the Rámri fossil tooth, I yet think, that as it seems to belong to a distinct species from the species now living in the Indian Ocean, and as it is very difficult to refer to specimens without distinct names, I shall do well if I provisionally call the fossil *Diodon foleyi*, after the discoverer of the Rámri specimen.

On page 35 of the 3rd part of the 1st volume of the IVth series of the "Palæontologia Indica," the Rámri tooth is referred to as of cretaceous age.

The occurrence of the fossil Diodon in the Eocenes around the Bay of Bengal, and the existence there of a living species, would seem to indicate that the genus has inhabited the Indian Ocean continuously since the Eocene.

CAPITODUS.

The genus *Capitodus* was made by Count Münster⁶ for the reception of certain jaws and teeth of fishes from the Miocene of the Vienna basin. These fishes were furnished with palatal, and peculiarly flattened incisor teeth. Count Münster classed them among the Ganoids; but M. Agassiz⁷ considered that they belonged to the Sparoid Teleosteans (Brems and Sea-Brems), which seems to be the more probable view. *Capitoilus truncatus* has been subsequently described from the Miocene of upper Silesia.⁸ I am not aware that any new species of the genus has been recorded since the original five species described by Münster. Some years ago, however, Mr. Wynne sent to the Indian Museum a fish-tooth from the beds overlying the nummulitic salt zone of Kohát, which by Dr. Feistmantel and myself has been determined to belong to the genus *Capitodus*. The tooth is one of the so-called incisor teeth, and has a broad, laterally expanded crown, the dentition of which is worn obliquely and concavely on the inner surface. The external surface is coated with hard shining enamel, and is convex laterally; the base of the crown is ankylosed to a bony pedicle, which must once

¹ Pictet: "Traité de Paléontologie," Vol. II, p. 123.

² *Ibid.*

³ *Ibid.*

⁴ Leidy: Pro. Acad. Nat. Sci., Philadelphia, Vol. VII, p. 397.

⁵ Quar. Jour. Geol. Soc., Vol. XXXV, p. 529.

⁶ Beitrage zur Petrefacten kunde, Bayreuth, 1839—46.

⁷ Bronn: Index, Paléont. Nomenclator, p. 214.

⁸ Roemer: "Geologie von Oberschlesien," Breslau, 1870, pl. XLVIII, fig. 4.

have joined the jaw. The width of the crown is 0.7 inch, and its height 0.4 inch.

The general form of the crown of this tooth, and its wear, is much like that of the incisor of *Capitodus truncatus*¹; the crown is, however, proportionally much wider in the Indian than in the European tooth. The other European species have still narrower incisors. The Indian tooth belongs apparently to a distinct species, which I propose to name *C. indicus*.

The strata from which the tooth was obtained are probably of upper Eocene age. The genus *Capitodus* seems to be closely allied to the living Sparoid *Sargus*,² but is distinguished by its broader incisors. The Indian species carries the genus back to the upper Eocene.

NOTE ON THE FOSSIL GENERA *Nöggerathia*, STBG., *Nöggerathiopsis*, FSTM., AND *Rhoptozamites*, SCHMALH, IN PALEOZOIC AND SECONDARY ROCKS OF EUROPE, ASIA, AND AUSTRALIA, by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India*.

In my Flora of the Talchir-Karharbari beds, I had occasion to notice what was then known regarding the systematical position of the genus *Nöggerathia*, and also to show the reasons why I thought that certain leaves of the Indian coal beds, described as *Nöggerathia*, differ from this genus in the proper sense; I accordingly named them *Nöggerathiopsis*, leaving them with the *Cycadeaceæ*. At that time I could not refer to the Australian *Nöggerathia*; but later examination and comparison have shown that the Australian leaves, also called *Nöggerathia*, do not generically differ from the Indian *Nöggerathiopsis*, and have therefore to be also classed with this genus.

In India the leaves seem to represent one species only, with about one or two varieties; they are known from (a) The Talchir-Karharbai group, and (b) from the Raniganj-Kámthi group.

In Australia this genus is known to begin in the lower coal-measures (below the first marine fauna), from which I described one species as *Nöggerathiopsis prisca*. It is more numerous in the upper coal-measures (Newcastle beds), from which two species of *Nöggerathia* were described by Dana; they should now, of course, be classed with *Nöggerathiopsis*.

There is a close representative of this genus in the Siberian Jura, *i.e.*, in the Kusnezsk basin of the Altai, and on the Lower Tunguska (tributary of the Yenissei river). From the former place, two species of *Nöggerathia* were described by Prof. Göppert³ as *Nögg. æqualis* and *N. distans*, and the formation from which they came was supposed to be Permian.

Quite recently, however, Mr. Schmalhausen has published a short paper on

¹ Münster: *loc. cit.*, Vol. VII, pl. II, fig. 2. Roemer, *loc. cit.*

² Owen: "Odontography," pl. XLII.

³ Tchihatcheff: Voyage dans l'Altai orientale, 1845.

the Jurassic Floras of Russia,¹ where the Flora of the Kusnezsk basin on the Altai is described as an undoubted Jurassic flora. Regarding the two mentioned species of *Nöggerathia*, Mr. Schmalhausen says, "The specimens described by Göppert as *Nögg. distans* and *N. æqualis* are apparently leaflets of a *Cycadeous* plant, related partly with forms of *Zamia*, partly with *Podozamites*. The name *Rhoptozamites* is proposed for the same." They are described as very numerous; with them occur *Phyllothea*, *Asplenium whitthiense*, Bgt., sp. var. *tenue*, *Ozekanowskia rigida*, Heer, *Pinus nordenskiöldi*, Heer, *Phönixopsis angustifolia*, Heer, *Sumaropsis parvula* Heer, and also *Gingko*, most of which occur in the Jura of Eastern Siberia and the Amur countries. Of *Cycadeaceæ*, the following were found: *Zamites inflexus*, Eichw., *Podozamites eichwaldi*, and a *Otenophyllum*.

The genus *Rhoptozamites* is equally numerous on the Tunguska river.

A comparison of the Indian and Australian *Nöggerathiopsis* with the original drawings of the Altai *Nöggerathia* (Göpp. l. c.) shows that they are remarkably close to one another, and the genus *Rhoptozamites*, Schmalhausen, is a Jurassic representative of the genus *Nöggerathiopsis*, which in Australia begins in palæozoic beds, in India occurs in the Talchir-Karharbari and Damuda divisions of the Gondwana system² and in Siberia has a close (if not generically identical) representative in Jurassic rocks.

There are now especially three genera: *Phyllothea*, Bgt., *Glossopteris*, Bgt., *Nöggerathiopsis*, Fstm. (and *Rhoptozamites*, Schmalh.), which begin in Australia in palæozoic rocks, and pass almost unchanged through the subsequent formations into Jurassic rocks in India and Siberia.

In my Flora of the Lower Gondwanas, I shall treat more closely of this genus, where I shall also refer to Count Saporta's recent papers on *Nöggerathia* and various plants included in this genus;³ as also to some recent observations on the fructification of the Bohemian *Nöggerathia foliosa*, Stbg., which modify to a certain extent the classification given in Mr. Saporta's paper.⁴

NOTES ON FOSSIL PLANTS FROM KATTYWAR, SHEKH BUDIN, AND SIRGUJAH by O. FEISTMANTEL, *Palæontologist*, *Geological Survey of India*.

I. JURASSIC PLANTS FROM KATTYWAR.

In 1878, Mr. Fedden, while surveying a portion of the Kattywar peninsula, collected some fossil plants preserved in a friable sandy shale of purplish grey color. They are only very fragmentary, although the fragments are numerous enough; but as a certain interest attaches to them, I think it worth while to name them and discuss, as far as possible, their relations. The plants were found three-quarters of a mile north-west of Than, Northern Kattywar.

¹ Beiträge zur Jura Flora Russlands, 1879. Mélanges physiques et chimiques, Tome XI, tiré du Bull. de l'Acad. Imp. d. scienc. d-St. Petersburg, Vol. XXV.

² Permo-Triassic—if the Talchirs are considered as representing a portion of the Permian.

³ Comptes Rendus des Séances de l'Acad. d. Sc., tome 86, 1878.

⁴ While this short note was passing through the press, I received Mr. Schmalhausen's paper with figures, but too late for notice. I shall do so at an early opportunity.

FILICES.

Group of *ALETHOPTERIS WHITBIENSIS*, Schimp. (Feistm.) or *ASPENIUM WHITBIENSE*, Heer.

There is one pinna of a fern which apparently belongs to this group of fossil plants, but it is one of the more slender forms, and is very closely related to the Jurassic *Asplenium argutulum*, Heer,¹ which also is to be included in the group of *Alethopteris whitbiensis*.

Alethopteris whitbiensis is known in India, especially from the Jabalpur and Umia groups; from the latter I have figured a specimen closely resembling that from Kattywar.

CYCADACEÆ.

There is only one small fragment, which, I think, belongs to the genus *Ptilophyllum*; it indicates one of the narrow-leaved forms, to which belongs *Ptil.* var. *minimum*, Fstm. from Kach (Cutch); the same was also found in the Sripermatur group of the south-east coast of India.

CONIFERÆ.

Representatives of this Order are pretty numerous, especially leaved branchlets and seeds, although the former in no large specimens. The branchlets appear to me to belong to two species.

Palissya jabalpurensis, Fstm. The specimens are a little smaller than the original form from the Jabalpur group.

Taxites tenerrimus, Fstm. Several specimens are certainly to be referred to this form of the Jabalpur group.

The seeds are:

Araucarites cutchensis, Fstm. These are numerous, of various sizes. They are known from the Umia group, Jabalpur group, and Sripermatur group.

Besides these coniferous plants, there are numerous fragments of long narrow leaves, with a central vein in the better preserved specimens. My belief is, that they also are *coniferæ*, and in this case they most probably belong to the genus *Pinus*, resembling very much *Pinus nordenskiöldi*, Heer.²

A comparison of these fossil plants shows that they are related to the flora of the Jabalpur group by the presence of *Palissya jabalpurensis* and *Taxites tenerrimus*, Fstm; while *Araucarites cutchensis*, Fstm. is common to the flora of the Umia and Jabalpur groups. There is also a fern corresponding with a form from Kach and a fragmentary portion of a *Ptilophyllum*. These, with the *Araucarites cutchensis*, Fstm., would correlate this flora also with that of the Umia group in Kach, as was noticed in the Annual Report of the Geological Survey of India for 1878.

¹ Juraflora Ost-Sibiriens, 1876 (Flora fossilis arctica, Vol. IV, 1877), Taf. III, fig. 7.

² Beiträge zur fossilen Flora Spitzbergens, Tafel. IX, figs 1-6 (Flora fossilis arctica, Vol. IV 1877); Beiträge zur Juraflora Ost-Sibiriens und des Amurlandes, Taf. IV, fig. 8c (the same Volume), and Tafel. XXII, p. 4, a b., XXVII, 9a XXVIII, fig. 4.

Both these correlations appear (as far as the plant remains show) to be equally justified; and this is certainly of no small interest, as this Kattywar flora thus forms a connecting link between those of the Jabalpur and the Umia groups, placing them, thus, homotaxially on the same horizon. This does not, of course, change anything of well established stratigraphical relations; and there is no objection that the same flora, which if considered from the Jabalpur group only has to be taken as middle Jurassic, should be found in the Umia group with and above upper Jurassic marine animals, and should still retain its middle Jurassic character, which view I maintain.

The case in Kach is, of course, easily solved: the formation is determined from the fauna, although this is associated with a flora of an older facies, but the question becomes more complicated where in the same beds there are found marine animals, of secondary and palæozoic types, as in the Salt-range, and in cases to be described by Mr. Griesbach from the Himalayan Trias.

2. NOTE ON SOME PLANTS FROM THE JURASSIC ROCKS AT SHEKH BUDIN (UPPER PUNJAB).

Last year Mr. A. B. Wynne made a collection of fossils at Shekh Budin, comprising a few plant-remains, which, although very fragmentary, are of great importance, as being the first plants collected during the work of the Geological Survey in this northern portion of India. They are, however, not the only plants found in Upper Punjab. Dr. Waagen, in his note on the Attock slates,¹ mentions that there are in the collection of the Geological Society of London several specimens of plants from the Salt-range, although no recognisable specimens were yielded from that ground to careful search by the officers of the Survey.

The plant-fragments of Shekh Budin are preserved in a fine, slightly micaceous shale, of a light purplish-grey color, resembling certain plant-bearing shales of the Jurassic rocks in Kach, but more closely the shales of the Jabalpur group, near Jabalpur. The plants also, as far as determinable, recall those of the Jabalpur group.

The only fossils determinable with some certainty belong to the—

CYCADEACEÆ.

Ptilophyllum (?) *acutifolium*, Mor.—There is a fragment of a leaf of a cycadeous plant, which belongs to the *Zamiæ* and which I refer to *Ptilophyllum*, for it appears from one of the leaflets that they are not free at the lower angle, but decurring; the upper angle, which is free, is rather a little more rounded than is usually the case in *Ptilophyllum*; but a specimen with very similar leaflets to those under discussion is figured as *Ptilophyllum acutifolium* in my Flora of the Jabalpur group,² Plate V, fig. 1.

Podozamites, sp.—There is another fragment of a single leaflet, traversed by longitudinal veins. This I refer to the genus *Podozamites*, and it appears to me

¹ Rec. Geol. Surv. of India, 1879, Vol. XII, Pt. 4, p. 184.

² Pal. Indica, Ser. XI, 2.

to represent the top portion, as the veins only approach each other without being dichotomous.

An identification of a fragment like this is always more or less uncertain, but in this case I think we can refer the fragment to *Podozamites lanceolatus* var. *eichwaldi*, Heer.¹

This, although very unsatisfactory palæontological evidence, would so far show that these plant-beds of Shekh Budín have to be considered as representatives of the Gondwánas in the Upper Punjab in association with marine beds—a case like that in Kach, and on the south-east coast of India.

3. LOWER GONDWANA PLANTS FROM THE AURANGA COAL-FIELD.

Mr. C. L. Griesbach, on his way to the Tatapáni and Rámkola coal-fields in Sirgudah, passed through the Auranga coal-field and collected a few fossils from a spot west of Murup, in beds mapped by Mr. Ball² as Barakars. Although I could only determine two species, I think them interesting enough for record.

Trizygia speciosa, Royle.—The occurrence of this fossil in this coal-field is of interest, as illustrating the geographical and stratigraphical distribution of the species. It was first made known from the Barakars of the Talchir coal-field, where it does not seem to be rare. Subsequently it was found to occur rather numerously in the Raniganj group of the Raniganj coal-field. This Raniganj form appears in general a little larger than that from the Barakars. Later on the same species was brought from the Barakars of the Bokháro coal-field by Mr. Hughes; and it is also known from the Bijori horizon (representing the Raniganj group) of the Satpura basin, in the upper Denwa valley; and now we know of it in the Auranga coal-field from the Barakar group. This species is thus almost equally numerous in the Barakar as in the Raniganj group.

There is no essential distinction between the Raniganj and Barakar forms, both show the characteristic “three paired” arrangement of the leaflets, the same distribution of the veins, etc. The only difference I could find is that already mentioned, between the forms from the Raniganj coal-field (Raniganj group) and Talchir coal-field (Barakar group); but the specimens from the Auranga coal-field (Barakar group) exhibit a size like that of the Raniganj form, so that even this character cannot be used as distinguishing the forms from these two groups, and both must be declared identical.

Glossopteris communis, Fstm.—This species is equally frequent through all the sub-divisions of the Lower Gondwanas.

4. FOSSIL PLANTS FROM THE TATAPANI AND RAMKOLA COAL-FIELDS (Surgudah).

Last year (1878) a good collection of fossil plants was brought by Mr. C. L. Griesbach from the Tatapáni and Rámkola coal-fields. The fossils are from various localities and from various horizons. Mr. Griesbach, in his forthcoming report on the geology of these coal-fields, indicates the positions of the fossils in

¹ *Juraflorea Ost-Sibriens und des Amurlandes*, 1877, Vol. IV, p. 109, Pl. XXVI.

² V. Ball: *Geology of the Auranga and Hutár coal-field (Palamow)*. Mem. Geol. Surv. of India, Vol. XV, Pt. 1.

each of his sections; it would, therefore, be unnecessary for me to discuss the fossils from each locality; it will be sufficient to speak of the fossils of each group collectively. In this area, the close palæontological relation of the several groups is also clearly illustrated, just as in the Satpura basin, especially, as it appears, between the Raniganj and Panchet groups; for there are fossils from several localities which, according to our present knowledge, correspond more with those of the Raniganj group, while the beds seem to be referable either to this group or to the Panchet group. I shall mention these localities further on.

The most interesting fact illustrated by the fossils brought by Mr. Griesbach is the satisfactory proof of the occurrence of the typical Raniganj group, as it occurs in the Raniganj field. This is shown especially by the numerous occurrence of *Schizoneura gondwanensis*, although, as we know, *Schizoneura* is not entirely wanting in the Barakar group, and is also not very rare in the Panchet group.

BARAKAR GROUP.

I come at once to speak of the fossils of this group, no fossils having been met with in the Talchirs, and also no equivalent of the Karharbári beds. As in the other coal-fields, there is here also no striking palæontological feature characterising the Barakar group, most of the fossils being common to all the sub-groups of the Damuda division, and its presence is with certainty demonstrated only stratigraphically; but a certain negative character can be used, *i. e.*, the absence (or rare occurrence in other cases) of *Schizoneura* (when compared with its numerous occurrence in the Raniganj group) and of certain forms of *Glossopteris*, which I shall mark presently as occurring in the Raniganj group, in which group the genus *Glossopteris* appears to be altogether more numerous.

I first enumerate the fossils from localities which apparently belong to the Barakar group (judged from the stratigraphical position); while at the end I shall mention several localities, about which, from a palæontological point of view, I can form no certain opinion.

1. *Equisetacea*.

Vertebraria indica, Royle.—The common form; found on the Sendur river, west of Mitgain; on the Ledho nalah near Karamdiha; between the Mahán river and the Tamor hill, near Majurdaki (southern field).

2. *Filices*.

Glossopteris communis, Fstm.—On the Sendur river, west of Mitgain; west of Chumra; on the Ledho nalah, near Karamdiha.

Glossopteris browniana, Bgt.—On the Sendur river, west of Mitgain.

Glossopteris (damudica), Fstm., MSS.—This is a species which, like *Glossopteris communis*, occurs through the whole of the Damuda series, but is apparently most numerous in the Barakar group and in the iron shales. I have not described it yet, nor has it been figured, but I nevertheless introduce the name, as I shall have to refer to it again when speaking of the Raniganj fossils. From the Sendur river, west of Mitgain; between the Mahán river and the Tamor hill.

Glossopteris indica, Schimp.—Between Mahán river and Tamor hill (Majurdaki); north-west of Reonti.

3. *Cycadeaceæ* (?).

Nöggerathiopsis hislopi, Bunb., sp. (Fstm.)—This species, at first known from the Kámthi (Raniganj) group only, was later identified from the Barakar and Talchir-Karharbári groups also. Between the Mahán river and Tamor hill (Majurdaki); Suidud nalah, 1¼ mile north of Bheria.

The localities, the fossils of which do not indicate with certainty the Barakar group, are:

(a). West of Dhonda, from where I could determine:

Glossopteris indica, Schimp, and

Glossopteris communis, Fstm.

(b). Suknai nalah north of Sarsera: from here I determine:

Vertebraria indica, Royle.

Glossopteris communis, Fstm.

There is, however, no objection that these localities also should be mapped as Barakar, as is done on Mr. Griesbach's map.

RANIGANJ GROUP.

The occurrence of the Raniganj group in the typical form is, I think, well established in this field by the frequent occurrence of *Schizoneura gondwanensis*, Fstm., and of several species of *Glossopteris*, which hitherto are known from the Raniganj group only; I shall mention them presently; one is already a described form, the others are new.

1. *Equisetaceæ*.

Vertebraria indica, Royle, the more branched form, as known from the Kámthi (Raniganj) group; between the Mahán river and the Tamor hill; nalah between Gouri and Ghui; in the Morne river, north of Parasdiha.

Schizoneura gondwanensis, Fstm.—Several pieces of shale are filled with specimens of this species, just as is the case in the Raniganj field, and also the shale agrees with that of the Raniganj field. The specimens are in layers, one over the other, preserved as leaved stalks of various sizes and as single leaves. It is additional evidence to the wide geographical distribution and frequent occurrence of this species in the Damuda series, especially in the Raniganj group.

We know this species at present from—

(a), the Raniganj group of the Raniganj coal-field, where it is very numerous; from the Jherria coal-field; from the Hingir coal-field; from the Tatapáni coal-field, where it appears to be also numerous; and from the Satpura basin, where it is known from two localities (in the Bijori horizon);

(b), from the Panchet group, in the Raniganj field, where it occurs pretty numerously.

(c), from the Barakar group on Lumki hill, in the Karharbári coal-field;

(d), from the Talchir-Karharbári beds in the Mohpáni coal-field, and (?) from the Talchir shales of the Deogarh field.¹

In the Tatapáni coal-field it occurs along the nalah at Budatand and near Lanjít.²

FILICES.

Glossopteris angustifolia, Bgt.; this narrow-leaved form is especially known from the Raniganj group.

Banki Nalah, between Chumra and Gidhi; between Mahán river and Tamor hill; Morne river, north of Parasdiha; Budatand nalah, near Budatand, south of Nowadih; in the Ledho nalah.

Glossopteris retifera, Fstm.—This also is a Raniganj form. Banki nalah, between Chumra and Gidhi.

Glossopt. communis, Fstm.—Banki nalah, between Chumra and Gidhi; east of Ghui; south of Nowadih; in the Ledho nalah.

Glossopt. indica, Schimp., between Chumra and Gidhi.

Glossopteris, sp., a peculiarly oval leaf, which, I think, will prove a new species. One specimen of the same kind is known from the Raniganj group of the Raniganj field, and also the rock agrees completely. The net venation is much like that of *Glossopt. communis*, but still finer and narrower, and the midrib diminishes suddenly towards the apex. I shall describe this form in the next fasciculus of the Lower Gondwána Flora. North of Meguli (Moholi on map).

Glossopt. damudica, Fstm. (MS.)—This species is already mentioned above. Morne river, north of Parasdiha.

Glossopteris, sp.—Another species was found in the Tatapáni coal-field, identical with one from the Raniganj field (Raniganj group), not yet described; it is a narrow leaf, with a large net venation, the veins passing out from the midrib at an acute angle. South of Nowadih.

From these fossils, the Raniganj group is certainly quite well established.

There are a few other localities, which palæontologically might be still placed in the Raniganj group, while stratigraphically they seem to be on the Panchet horizon.

a. Nalah west of Narola—

Glossopteris, sp.

b. In the Ledho nalah—

Glossopteris angustifolia, Bgt.

Glossopt. communis, Fstm.

Glossopt. indica, Schimp.

c. Near Karamdiha—

Glossopteris communis, Fstm.

¹ The specimens appear at least to be *Schizoneura*.

² This portion of the Lower Gondwánas near Lanjít is colored as Barakars, the strata being much broken up by dykes, etc., so that no distinction of beds could be made out. The frequent occurrence of *Schizoneura gondwanensis*, Fstm., at this place would refer that portion to the Raniganj group.

These localities thus yield an unusually large number of *Glossopteris*, while in the Panchet rocks, although its occurrence is undoubtedly established, it is only known to occur rarely, and fragmentary. At these localities, however, it occurs in the same manner as in the Raniganj group, and we have either to acknowledge the closest connection of the Panchet and Raniganj groups (which in this field also seems to be shown stratigraphically), or to account for the uninterrupted passage of the Raniganj flora into the Panchet group, in which case the close relation of both is again shown. It is, of course, possible that the observations upon which these suggestions are based might be modified by a revision of the survey, but taking the lines as laid down by Mr. Griesbach, we may now say that three-fifths of the species in the Panchet group are those of the Raniganj group.

This mutual relation of the Raniganj and Panchet groups in this field, is so far interesting and important, as at the two last-named localities there occurs a plant which appears to be a *Thinnfeldia*. I shall describe it more closely in my Flora of the Lower Gondwānas.

MAHADEVAS.

In succession to the Raniganj-Panchet rocks the Mahadevas are highly developed, as in the Satpura basin; and they have proved equally poor in fossils. Mr. Griesbach discovered only at one locality some fragments of plants, which do not admit of specific determination: one is an *Alethopteris*; the other is doubtful, even as to the genus; it is either a *Teniopteris* or *Glossopteris*.

The Mahadevas in this area seem to be to the Panchets in the same close relation as in the Satpura basin, where the whole Gondwāna system is developed, from the Talchirs (bottom) to the Jabalpur group (top), and these basins where the succession of the several groups is also continuous, are, therefore, of the same interest for the correlation of the various groups.

ON VOLCANIC FOCI OF ERUPTION IN THE KONKAN, by GEORGE T. CLARK, ESQ.¹

I chanced yesterday, in the library of the Athenæum Club, to meet with the two volumes upon the geology of India to which are prefixed your name and that of Mr. Blanford, and in vol. 1, page 327, I lighted upon some remarks very complimentary indeed to myself, but which do not, I think, refer quite correctly to what I advanced, now thirty years ago, on the geology of the western side of the Indian peninsula, in the neighbourhood of Bombay. I therefore address myself to you by letter, and I must ask you to excuse the length into which I may probably be betrayed.

At the time that I reached Bombay in 1844, nothing was known about the origin of the trap of Western India, and I found from Mr. Orlebar, and, I think,

¹ Mr. Clark's observations and views upon the trappean rocks of Western India are much more clearly brought out in the letter (dated 25th July 1879) published above, than in his original papers in the Quarterly Journal Geol. Soc., London, Vol. III., p. 221, (1847) and Vol. XXV, p. 164 (1869), from which the notice in the Manual was taken. The obscurity upon the important question of denudation is now quite cleared up.—H. B. MEDLICOTT.

from Mr. Malcolmson, both very competent geologists, that even Bombay and Salsette had not been geologically examined, and that little was known of their details and still less of those of the Konkan on the opposite side of the harbour. Feeling much interest in the subject, I determined, while visiting the Island and the main land for other purposes, to pay what attention I could to the geology. I began with Bombay, and spent some time in laying down the dip and direction of its rocks, which I found to be mostly igneous, traps and greenstones, with occasional intervening beds, probably of sedimentary origin, all dipping more or less westward at a high inclination. While thus engaged I was fortunate enough to fall in with a bed, newly uncovered, containing very perfect remains of batrachians, which lay immediately beneath a sheet of basalt capping the western side of the Island of Bombay, and which was evidently its latest formation. I sent home to the late Dean Buckland some specimens of the fossils, which were figured in the *Journal of the Geological Society* (Vol. III, p. 224), and thus the geological date of the basalt was established. I found the same dip and bearing to prevail in Salsette.

On reaching the Konkan, and pausing near Kalian, I was much struck with the difference between the outline of the eastern and western eminences. The hills of Salsette were sharp-topped and steep, all their lines more or less inclined and covered to the top with vegetation, whereas the hills, or rather mountains, of the Konkan, were flat-topped, their leading lines horizontal or nearly so, their sides terraced, the terraces divided by cliffs, and the tops, at least, bare of vegetation. It seemed as though in the one case the beds, being tilted, had allowed the rain to penetrate and produced disintegration, while in the other, the beds being flat, resisted penetration and its consequences. It was also clear that the eastern mountains, as Towlee, Bhow-mulling, and Matheran, were outliers from the great mass of the Western Ghauts, strictly conformable to them in their structure, and that the dip of their beds, so slight as to appear locally horizontal, was really towards the east, and with a remarkably uniform inclination.

This contrast, obvious at the first glance, led me to suppose that the origin of the traps must be sought for either in the trough of Bombay harbour or in the adjacent margin of the Konkan, or wherever the beds dipped from a centre or central line. It was further evident, with so complete a correspondence between the beds of the outliers and the main range, that the whole must at one time have been continuous, and that a vast mass of intervening matter must have been excavated and removed.

Following out these ideas, I proceeded to examine the floor of the Konkan, at first along its western edge towards Panwell, and then more minutely along a line which pointed westwards from Kalian towards the great bay of the Malsege Ghaut, and which presented some very remarkable appearances.

The rock beds, so far as I observed, at or near the level of the floor of the Konkan, which was not much above that of the sea, were all of a uniform variety of trap, and all amygdaloidal, the vesicles being mostly filled with zeolite. Usually the lower part of each bed was more or less solid, and the upper part vesicular. The vesicles were of all sizes, up to a length of 12 or 13 inches and a diameter of 3 or 4, and they were frequently elongated, as though the trap,

while viscid and full of air bubbles, had flowed in the direction of their longer axis. Occasionally also the vesicles were bent and twisted, as though the trap had flowed over a hard edge, as water over a weir; particulars which seemed to afford a clue to the direction, and in some degree to the circumstances, of the flow. Following upon these indications, I found that I reached a number of hillocks or cones, hollow in the centre, and often with a gap in one side, and within and about these the trap often lay in small streamlets, crossing over or overlapping one another, but all evidently derived from a common source or centre. Frequently these streams had flowed for some distance in parallel lines impinging upon each other, not uniting, so as to leave a V-shaped trough between them, which again was filled up with other streamlets. All these had assumed various shapes according as they had flowed in a trough or over a flat surface, or over an obstacle, or had dropped over some accidental step or fissure in the subjacent rock.

These singular, crater-like, hillocks lay very thick together along the course of the Bervee river above Kalian, and upon that of the upper Kaloo near Bhallow and Kinnowlee. Near the ancient temple of Oombernaut are several, some with a central hollow a quarter of a mile across and sides from 200 to 300 feet high. The interior slope is much steeper than the exterior, and the floor is usually very hard and undulating, as though it had been in a state of ebullition.

Besides those hillocks are also a number of flattened domes very distinct, though of no great height, like huge bubbles of very hard rock, and seen, where the surface is broken, to be composed of layers like the coats of an onion.

These are especially frequent in the upper Kaloo approaching the Malsege. I observed also in the bed of this river, dry or nearly so when I saw it, that in many places it was not excavated as by water, but formed by the parallel junction of two lava streams, the stream filling up which had been dissected out, not eroded, so that the surfaces remained smooth and sometimes almost glazed.

All these appearances led me to believe that I had lighted on a number of foci of volcanic or plutonic action, placed along certain lines, and that these were the vents—perhaps sources would have been a safer word—whence the traps of the district, and of the adjacent islands on the one hand and of the Ghauts and Deccan on the other, were derived. I came also to the conclusion, perhaps upon the examination of too limited an area, that the general line of the sources lay nearly north and south down the edge of the Konkan, pointing towards the islands of Heneri and Keneri, and that the line towards the Malsege was a sort of spur or lateral axis, accounting probably for the existence of that very remarkable bay or indentation into the main line of the Syhadree range.

The contrast was remarkable between the irregularity of the streamlets of lava in the plain and near the sources above described, and the excessive regularity of the beds at higher elevation, and at a distance from those points.

This indeed was what might have been expected; a regular and uniform dip being more likely to be arrived at by a lava sheet at a certain distance from its source.

But the above are not the only remarkable features connected with these sources. There are found generally, in the Konkan, large numbers of basaltic dykes, more or less vertical, and usually running in lines straight or nearly so. These are of various breadths, up to 40 feet or even more, and they occur most frequently near the sources or craters described above. Thus there are numbers of them about the Bervee between Kalian and Budlapoor, and they are especially thick between Moorbar and Kinnowlee, and at the head of the Malsege bay, under Sindloo and Hurreechunder. Not only are they found in the floor of the Konkan, but they are seen to cleave the highest eminences of the ghauts, and they extend for some miles in to the Deccan, showing that they were poured out and injected after the great mass of the trap was laid down. It is remarkable also, that though so broad and extended so far as I saw, they are rarely, if ever, connected with any displacement of the intersected beds, or anything like a fault. It is remarkable also that the basalt which in Bombay is spread out as a sheet over the highest of the trap and greenstone beds, also caps the elevations of the ghauts, as may be seen at Khardalla, Beema-Shunker, and other places, though whether these horizontal sheets were caused by the overflow of the dykes, or whether, as is more probable, their material overflowed the craters in the usual way after the trap period had ceased, I could not ascertain. It is, however, evident from the mechanical position of the basalt whether in dykes or sheets, as well as from its relation to the batrachian fossils, that it was thrown up after the trap; and probably both dykes and sheets, though not simultaneous, belong to the same geological period.

The basalt dykes deserve close attention. They are generally vertical, and very rarely magnetic. Also they are almost always composed of small prisms, the axis being at right angles to the course and faces of the dyke. Also they are commonly fringed at each face, the fringe or 'selband' being broken up by vertical planes, parallel to the face of the dyke. The dyke beneath the fort at Kalian is columnar. The basalt is usually homogeneous, though now and then its surfaces are pitted as though small deposits of minerals had been washed out. There is no cohesion between the prisms, so that the dyke is often a mere trough, the matter being removed. Near the Wanaghaut where a large dyke cleaves the nearly precipitous face, the basalt is so far removed that the dyke is represented by a hollow chasm, and forms a steep stair-case, up which is a path for foot passengers.

Although there is no vertical displacement connected with these dykes, the heat of the basalt has hardened and rendered tough the contiguous trap. The effect of this is curious. In the plain near Moorbar the country is intersected by a net work of steep and narrow banks from 100 to 200 feet high, somewhat resembling the junction of a number of lines of railway in embankment. The axis of each of these banks is a dyke, the toughness imparted by which has enabled the banks to resist erosion, while the place of the dyke is marked by a trough a few feet deep, out of which the basaltic prisms, being loose, have been removed.

Looking back to the immediate causes of the very peculiar configuration of the

country between the ghauts and the sea, it occurred to me that what I there saw was not unlike what would be seen if the island of Sicily were to be submerged, and Etna be acted upon by water currents. The central part, being shattered, would easily be removed down to the nuclei of the several craters, and the flanks of the mountain being much less shaken would remain and present more or less of a scarp at their innermost and highest edge, and their surface, like that of the Deccan near the ghauts, would be hollowed into ordinary valleys of excavation. If for a single central point one or more lines of action were substituted, the effect would be pretty much what is now seen in the Konkan. Possibly the same effect would be produced by atmospheric action, only in such a case an enormous period of time would be necessary.

Then, as to the contrast between the beds forming the ghauts and those in Bombay and Salsette, the former at a certain distance from the line of action fall with a uniform and gentle slope, whereas the western beds fall at an opposite and much greater dip, and are more or less broken. This I supposed to be due to the previous configuration of the ground. I thought the base of Konkan and the Deccan to be a mass of metamorphic rock, over which the trap flowed at an easy slope, while to the west the same trap flowed into the deep sea. I understand, however, that late researches are opposed to this latter notion, and that there is reason to think that the greater dip of the western bed is due to a subsequent subsidence. This, of course, does not materially affect the question of the common sources of these rocks.

I remark also that the present, and I dare say the correct, opinion is that these traps are subaerial and volcanic. I supposed them to be submarine and plutonic, because they seemed to me to have been erupted under immense pressure. This again does not materially affect the leading inferences derived from my observations.

In concluding this long and, I fear, tedious letter, I may be allowed to remark that it is many years since I have paid attention to this or any other geological subject, and that neither formerly nor now have I any pretensions to be called a geologist. I brought home with me a vast collection of samples from every dyke I met with, each labelled with the direction, breadth and leading features of the dyke. I sent these in 1848 or 1849 to the Geological Society, where they were seen by Mr. Horner and the then Secretary Mr. Lonsdale. These gentlemen, however, did not think them worth the space they occupied, and as they declined them, I caused them to be thrown away, nor did I again trouble myself on the subject, until some years afterwards I saw to my surprise my name mentioned in a paper by Mr. Wynne as one of the pioneers in the geology of Bombay.

I am not sorry even now to find or make an opportunity of bringing under your notice as the head of the Indian Survey a sketch of what I did in the field so many years ago. You are necessarily aware of the difficulties attendant upon field work in the Konkan, and will therefore extend to my labours that charity that I suspect they much require.

I add a tracing of a map showing a few of the centres of action, and most of the dykes observed in the Malsege or towards Kalian.

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Two spinel-rubies, with a specimen of the matrix: from the Jagdalak mine.

MAJOR STEWART,
*Corps of Guides.*Verde antique serpentine, from Shigar, Ladák: it is locally called *Yessham* (jade).

MAJOR BIDDULPH.

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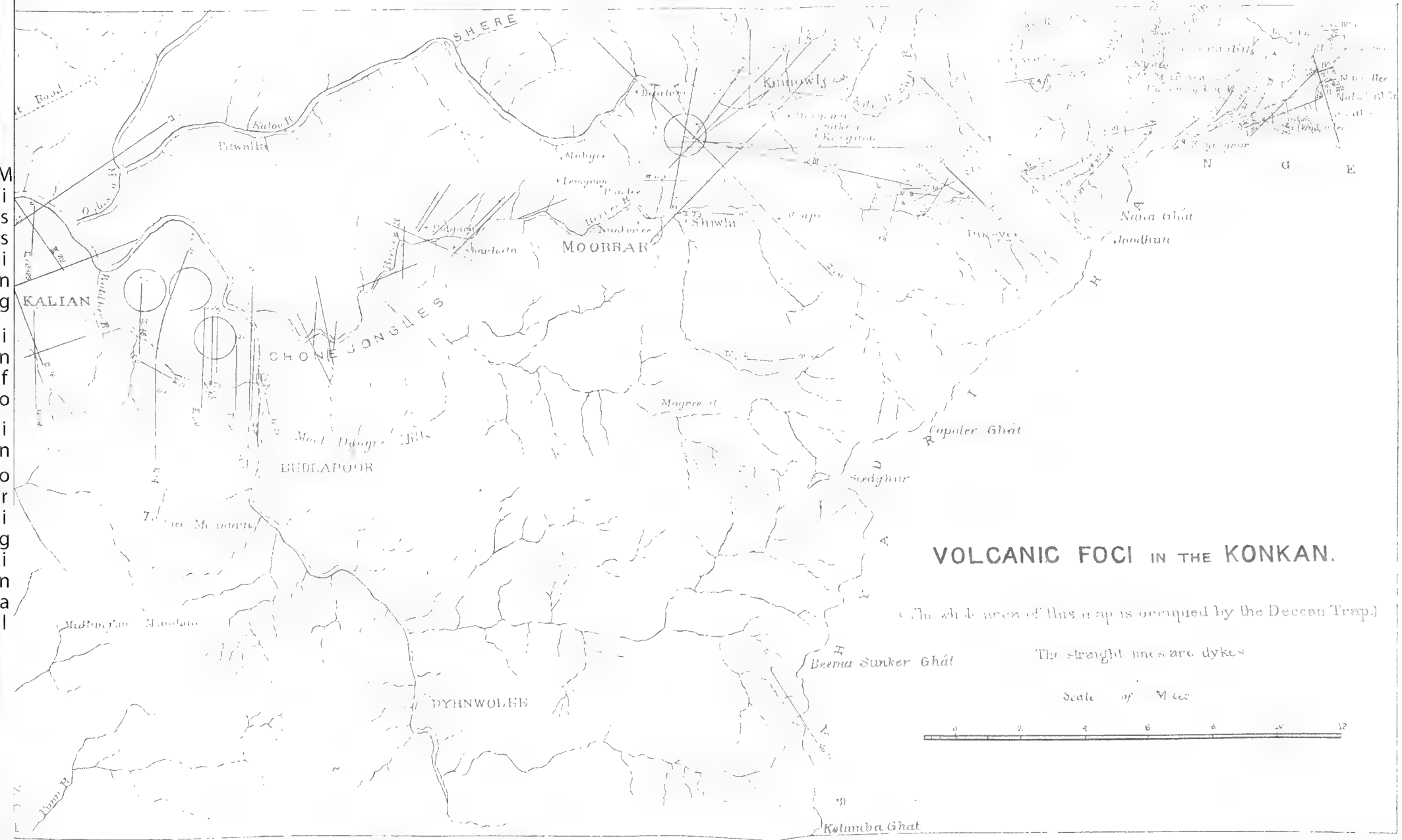
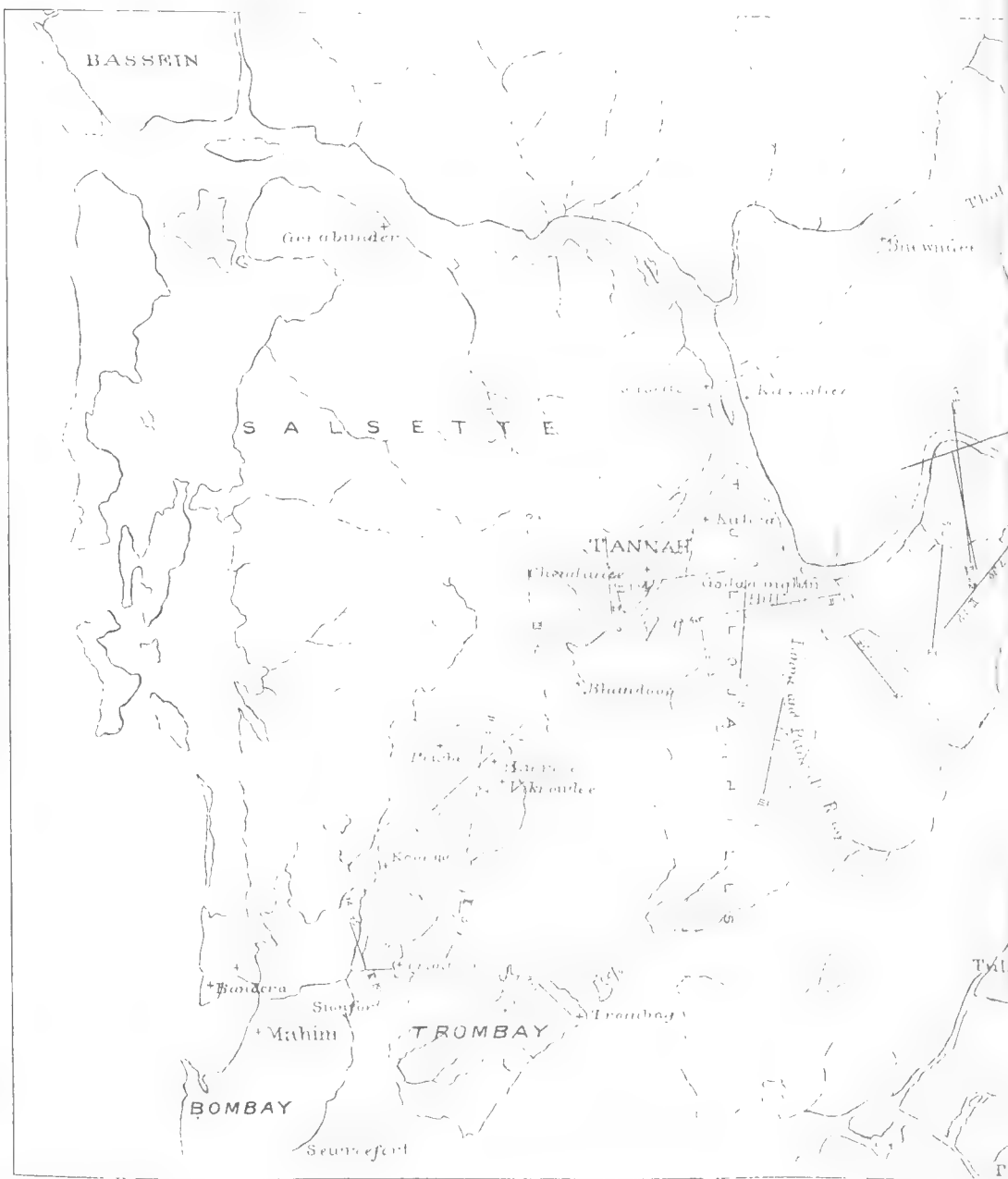
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DEPT. OF THE INTERIOR.



Missing information original

VOLCANIC FOCI IN THE KONKAN.

(The whole area of this map is occupied by the Deccan Trap.)

The straight lines are dykes

Scale of Miles



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RECORDS
OF THE
GEOLOGICAL SURVEY OF INDIA.

Part 2.]

1880.

[May.

GEOLOGICAL NOTES by C. L. GRIESBACH, F.G.S., *Geological Survey of India*.

1. *The metamorphic rocks of the Himalayas.*—It is not my intention to describe here in detail the rocks composing the Himalayas; for this I may refer the reader to the pages of the Manual and the Memoirs. I will only state that I could not see any material difference either in lithology or any other character between the metamorphics of the plains of India and those of the hills. Here as there we have a great deal of gneissic rocks of a porphyritic structure, traversed by many veins of granites of various character, and in that, I may here mention, these rocks reminded me forcibly of the granitic gneiss of the Cape, with its large felspar twin-crystals, to which Hochstetter has long ago drawn attention. Here as there we have folds of metamorphic schists of every lithological variety, traversed by hornblendic dykes, probably old trap outbursts. And both in the Peninsula and the Himalayan chain, the average strike of the metamorphic rocks is somewhere from east to west, and in that also these rocks correspond with the metamorphics of South and Eastern Africa.

When traversing the Southern Himalayas from south to north, two gneissic areas are met with, parallel to each other, and extending more or less along the whole known part of the mountain chain. The first line is in the lower mountains south of the main chain, and in the Kumaun section the Almora hill is a point in that line. Further north is the main gneissic area of the great southern or Indian snowy range, with Nandadevi, Trisul, Mana, and other giants rising far above 24,000 feet. Between and skirting these gneissic lines, a series of metamorphic schists form most of the intermediate ground. In the Kumaun sections, they are found to dip north inside the first range (Naini Tal, etc.), and to pass with the Almora gneiss below the Bageswar limestones; in this formation the dip is rolling, once south, then north again, and finally it appears to pass under the second and great central gneiss area, but in reality the strata form with the latter a great fold, the upper part of which has been removed by denudation. On the other side of the gneissic area the schists re-appear again, reclining on the gneiss, and finally dipping below the old slate formation, which I shall presently prove to be not younger than Cambrian.



FIG. 1.—Section of the Himalayas between the Tatal and Milam, in natural scale.
1, Gneiss with granite veins. 2, Schists. 3, Cambrian slates and limestones. 4, Silurian. 5, Tertiary series of the Phabar.

The features may roughly be sketched as shown in the annexed section, in which I have, of course, omitted all the numerous minor folds and a few faults and dislocations which must of necessity occur where such enormous tension existed.

2. *Pre-Silurian rocks of the Himalayas.*—Nearly all sections through the Himalayas reveal on the northern slope and below the fossiliferous Silurian series a formation which has often been noticed and always been described as the “Slate series.” The lowest member of it is probably a greenish silky and semi-metamorphic slate, seen near Milam to pass into the schists below. But higher up it passes soon into a purple or dark blue quartzite in thick beds associated with beds of a peculiar jasper-like conglomerate, which in some sections forms the lowest bed near the contact with the metamorphics. Not a single trace of fossils has been found in this group, which is very much contorted. It is now crumpled up into a narrow strip, so that its thickness cannot even be guessed at.

Higher beds, consisting of silky greenish slates, quartzites, and lastly, of a dense red quartz-slate, seem at a few places to rest unconformably on the lower group, and everywhere dip below the fossiliferous *Lower Silurian* formation.

A few indistinct traces of Bivalves, and *Pleurotomaria*? *Bellerophon*? were found in it. There is very little doubt as to the propriety of classing these last rocks with the *Cambrian* series of elsewhere, on the grounds of their relation to the overlying strata, which by their fossil contents are abundantly proved to belong to the *Lower Silurian* system. The lower group of quartzites and conglomerates may then be termed *Lower Cambrian*; and the whole rests more or

less conformably on the underlying metamorphic series, and shares with the latter in the general folding and disturbance of the strata.

In one or more of the folds of metamorphic rocks shown in the section, fig. 1, I found inclosed and folded into a narrow strip a mass of limestones, calcareous conglomerates and shales, here and there silicious, which at once reminded me of the Cambrians of the northern slope of the Himalayas. There the conglomerates consisted entirely of quartzites, the same as the cementing matrix, and formed with the latter a very hard jasper-like rock. Here the conglomerates are a hard grey, silicious limestone, pebbles as well as matrix. I believe that the Bageswar limestone really represents a limestone facies of the slate series or Cambrian; and in connection with the folding of the metamorphic series I consider them part of the same marine development of the Cambrians, now severed from the strip north of the central fold by the erosion of the upper arch of the anticlinal.

As indicated in the sketch section, fig. 1, I include the Naini Tal (Cheena) limestone for the present in that old Cambrian formation. Though the relations of this rock to the neighbouring tertiaries and basaltic traps is not quite clear, it seems best for the present to class them with the Bageswar rocks, with which they have much in common. The Naini Tal beds seem to dip below the metamorphics, but in reality rest above them and merely conform with them in a curve, which, as nearly all the larger ones in this section, have lost the upper arch by denudation, as shown in the above-mentioned section. It is needless to state here that the Naini Tal limestone has been compared with the Krol limestone of Simla.

3. *The Pre-Silurian rocks of the Peninsula.*—In Central and Southern India there is found a formation, covering the metamorphics in patches, and in some places overlaid by the Vindhian sandstones. Various are the strata occupying this position between these two rock groups, though mostly silicious, here and there calcareous, with beds of conglomerates, and as yet believed to be wholly unfossiliferous. Last year whilst traversing the Vindhian range on the Sone river, I observed a series of rocks, jasper-like conglomerates, quartzites and grey, almost crystalline limestones underlying the lower Vindhian sandstone near Agori Khas, which afterwards I could not help but compare with the similar rocks of the Himalayas. Here as there they rest directly on the metamorphic rocks.

4. *The Palæozoic rocks of the Himalayas; Silurian to Carboniferous.*—Directly resting on the Cambrian slate series I found a group of rocks as follows:—

Hanging: Lower Trias.

(About) 350'	white quartzite with	} Carboniferous	...	... 4
350'	red crinoid limestone			
666'	coral limestone	...	Devonian ?	... 3
1,129'	quartzite and slates	...	Upper Silurian	... 2
203'	coral limestone	...	Lower Silurian (Caradoc)	... 1

6,573'

Lying: Upper Cambrian.

I will not now enter into the description of this series, all the beds have proved rich in fossil contents, excepting group 3, which has only yielded a few casts of *Orthoceras* and a few Corals, which may be either Devonian or Carboniferous. Most of the fossils have already been described by General Strachey, and Messrs. Salter and Blanford. It is an uninterrupted series of beds, passing one into the other almost imperceptibly, but bearing unmistakable fossil evidence, the lowest bed of which, above the Cambrian slates, contains many of the English Caradoc forms, and the uppermost member of which group of rocks (the white quartzite) contains true Carboniferous brachiopods.

5. *Break between Carboniferous and Trias.*—The close of the Carboniferous series marks a great change in the Himalayan area. The next succeeding series of rocks resting on the Carboniferous is the Trias, ushered in by its lowermost member, the *Alpine Werfen beds*, with all its characteristic fossils. In some of the sections the contact of the two groups is apparently perfectly conformable, but the absence of the white quartzite in some sections, when the dark bituminous and micaceous Trias-base rests directly on the Red Crinoid limestone, besides the total absence of the Permian group, clearly points to a change of conditions, which must have taken place, at least here, after the close of the Carboniferous epoch. The explanation of this must be sought elsewhere.

6. *The Palæozoic rocks of South Africa.*—Some time ago I had the good fortune to be able to study three great cross-sections through South Africa and part of a fourth, namely—

- (1) From Table Bay to the Great Karoo;
- (2) From Algoa Bay inland;
- (3) From Port Natal to the Drakensberg; and
- (4) About 200 miles up the Zambezi on the east coast; but this latter is made very complete by the help of the observations of the late Mr. R. Thornton, the geologist of the first Livingstone expedition, whose extensive journals were placed in my hands by the Royal Geographical Society.

But one of the best sections, and also the earliest described, is the first,—between the Table Bay and the Great Karoo, a distance of about 140 miles. As this one illustrates all the features for comparison with our Indian formations, I will select it for the purpose.

The lowest rock seen is a gneissic and porphyritic granite, which forms the base of the Cape Table-mountain, of the Devils-peak and Lions-rump. It is seen in several places along the section cropping up with other metamorphic rocks beneath a slate formation, containing fossils. This slate formation probably represents all the lower palæozoic rocks. The great mass of it appears to be of *Devonian* age, proved so by an abundant fossil yield. It is very probable that also the lower palæozoic formations are there represented, as Hochstetter has already hinted at,¹ and recent finds of fossils make this very probable.² The whole is very much contorted and rolled up, evidently by a side pressure coming

¹ Dr. F. von Hochstetter: *Reise der Oesterr. Fregatte Novara*: Geol. Theil., p. 32.

² H. Woodward: *Quar. Jour. Geol. Surv.*, 1872, p. 31.

from the south,—the general strike being about east to west or nearly so. Devonian beds with almost the same fossil contents are found in the Falkland Islands, South America.

Quite unconformable on it lie the so-called Table-mountain sandstones. I need scarcely say that, as the name implies, the stratification is almost horizontal, sometimes quite so, thus forming a marked physical feature in the landscape. They are made up of red and brown gritty sandstones, of hard quartzites and partings of silicious shales.

When I crossed the Vindhians last year, I was at once, and forcibly, reminded of the South African tablelands, not only by the similar scarped outlines, but also by the similarity of lithological character.

A few thin seams of coal have been found in the Table-mountain sandstone, and a few badly preserved traces of fossil plants, probably of *Lepidodendron*, pointing to a Carboniferous age and to fresh-water conditions. As Hochstetter has already pointed out long ago, the Table-mountain sandstone is enclosed between the Devonian formation on one side and the lower Karoo beds on the other; the latter are most likely of Triassic or Permian age, so therefore the age of the Table-mountain sandstone becomes, as a matter of course, Carboniferous.

The close of the Carboniferous epoch marks a great change of conditions here. A steady pressure from the south, which before had already lifted the Devonian deposits above the level of the sea before the deposition of the sandstones, resulted in crushing and faulting of parts of the horizontal beds of the Carboniferous, and a further rise of a fringing southern belt of the Table-mountain sandstone, with a corresponding depression northwards, in which the first deposits of the Karoo series could be laid.

We see therefore that it is with the *close of the Carboniferous that changes of conditions begin, and an entirely new series of forms appear of a decidedly mesozoic type. There is a break*, into which nothing will fit, but perhaps a widely extended boulder bed at the base of the succeeding Karoo beds, and as yet found devoid of organic remains.

7. *The Indian Peninsula during the palæozoic epoch.*—As noticed above, a series of rocks of a semi-metamorphic character occupies in some parts of Central and Southern India the position between the metamorphics on one side and the Vindhian sandstone on the other. These rocks have received many names and are described at length in our Memoirs. Since all are older than the Vindhians, and in some respects analogous with the marine Cambrian deposits of the Himalayas, I may class them together as representing the Cambrian series. With the Cambrians of the Central Himalayas they have this structural character in common, that they share with the underlying metamorphics in all disturbances which have affected the latter both in the hills and in the Peninsula, and that the succeeding formation shows, in places at least, an unconformity. As I have shown above, there is an uninterrupted series of marine palæozoic rocks to be found on the north slope of our Himalayas; not a single member of the marine series is met with south of the central range, and it is fair to assume that the present central range marked the palæozoic boundary between land and ocean, or very nearly so. If my assumption is correct that the pre-Vindhian rocks are identical

with the Cambrians of the Himalayan area, then it is also certain that the change of physical conditions took place near the close of that epoch, and this is proven by the unconformity which marks the junction with the overlying rocks, in the hills the Silurians. Now, assuming that this break after the pre-Vindhian epoch corresponds with the one which occurs after the deposition of the Cambrians in the hills, we further perceive that on one side (Himalayas) we have a great series of marine palæozoic rocks, whereas on the other side (the Peninsula) only a mass of sandstones, quartzites, and shales is found next in succession. From henceforth the physical conditions of the peninsula are those of *terra firma*, and it is beyond doubt that some of the sandstones may represent one or more members of the palæozoic series. It has before been assumed that the Vindhians may be Silurian, perhaps even pre-Silurian, but I argue that the Vindhian sandstones, &c., represent the *whole* of the palæozoic rocks up to the close of the Carboniferous, and that there was not a long continued break between the deposition of the last Vindhians and the lowest Gondwana rocks. Ascending the scale of palæozoic rocks in the hills we find an unbroken series until we reach the close of the Carboniferous rocks, where we find a *break*—Triassic rocks of European type resting directly on Carboniferous. Some disturbances must have taken place to produce this break, changes of physical conditions which must have affected the Indian Peninsula. Now, if we search for the signs of these changes south of the central range, we notice the first unconformity, the first break between the Vindhians and the Talchirs. There is therefore good evidence that the former are simply the freshwater facies of the whole of the palæozoic series and that the Upper Vindhians represent the Carboniferous formation. And indeed this is likely enough if we compare this group with the similar Table-mountain sandstone of the Cape; these two groups not only resemble each other in petrological characters, but occupy relatively the same geological position.

8. *The mesozoic formations in the Himalayas.*—On the Carboniferous in the Kumaun sections, and on older rocks elsewhere probably, we find the mesozoic series ushered in by beds corresponding to the Bunter-Sandstein of Europe, or more correctly to the *Werfen* beds of the Alps. I was able to distinguish the following groups of the Trias and Rhætic':—

Rhætic	{	<i>Avicula contorta</i> beds	}	2,213'
		Lithodendron-limestone (<i>Megalodon triquetus</i>) with several partings of fossiliferous beds, probable representatives of the lower Kössen beds of the Alps	...	...	...	...
		Dolomites with partings of Lithodendron-limestone	...	...	...	...
		Brown limestones with greenish shales	...	...	...	782'
Trias	{	Greenish shales	160'	}	1,662'
		Black limestones, with splintery shales	...	...	...	483'
		Grey limestones	...	...	...	50'
		Limestone, earthy	...	...	...	3'
		Campiler } (Werfen beds)	...	...	...	184'
		Seisser						

¹ For a more detailed description and correlation of the Triassic and Rhætic series, I refer to the companion paper in this number of the Records "*Palæontological notes on the lower Trias of the Himalayas.*"

The topmost bed of the Rhætic passes into a thin bed (which is wanting in some sections) containing already Liassic forms, but after that a break occurs. Not a single member of the lower Oolite is found, the only representative of the Oolite (the well-known Spiti shales) contains forms of the upper-middle Oolite. The upper Jurassic beds are quite unfossiliferous dark shales. On them rest cretaceous greenish shales (olive shales of the Punjab?) and quartz sandstones capped by a white limestone with many cretaceous fossils (Stoliczka's Chikkim limestone).

9. *The mesozoic groups of the Peninsula.*—As already explained in the above notes, we meet with the first great break of deposits of the Peninsula between the upper Vindhians and the lowest Gondwana rocks, a break which I have tried to demonstrate must represent the break which is found between the Carboniferous and the Trias groups of the Himalayan area, and which therefore falls into the Permian epoch, an epoch which, both in Europe and North-Western Asia, represents a passage between the Palæozoic and Mesozoic types of life.

We know that great changes of land and water took place in the Australian region during Carboniferous times, and partly continued during the following periods. Into that epoch fall the deposits of the lower group of beds containing many plants of carboniferous aspect, described by Dr. O. Feistmantel¹ and associated with forms again met with in the shales and silty beds of the Talchirs and Karharbari group, figured and described by the same author. We must assume a disturbance of some continuation and magnitude to explain both the unconformity of the Talchirs on Vindhian and the Trias on Carboniferous series in India; accompanied as it is by an influx of forms belonging to the upper Carboniferous of Australia, it is only fair to assume that a pressure was exerted towards India from the south-east, causing a successive "landwave" to transmit eastern forms of terrestrial life, to travel west and perhaps northward—to India and China.

I believe the direction of this great landwave to have been nearly at right angles with the line of strike of the older north-east wave, which caused the distribution of land and water to change during palæozoic times, traces of which are found in the post-Cambrian both in the Himalayas and the Peninsula.

We see the existence of these two waves clearly exemplified in the present shape of the Peninsula not less than in the long folds of the Himalayas, extending in a north-west to south-east direction across Asia, forming a series of parallel ranges of great elevation, and also in the more or less latitudinal strike of the folds of older rocks of the Peninsula of India and of South Africa, the great river valleys of which two areas indicate this direction by their course. These palæozoic folds are traversed by folds (accompanied by local dislocations), running (nearly) in a north-south direction across the ranges, now deepened by the eroding agencies of glaciers and rivers, and which have shaped the beds of the palæozoic rocks into more or less dome-shaped masses, like so many enormous and inverted cups ranged side by side in the ranges of the Central Himalayas. Not less is it demonstrated by the direction and composition of the Burmese

¹ Palæozoische und mesozoische Flora des östlichen Australiens. In Palæontographica, Suppl. III, Lief. III, Hft. 4, 1879.

chain of hills, where we find Triassic marine beds immediately in rear of the advancing "landwave", which brought mesozoic forms of life to India from Australia.

It is at least probable that the later Carboniferous forms wandered westwards from Australia during Permian times and reached India in that epoch; in the wide basin-shaped folds of the crystallines and oldest palæozoic rocks of the peninsula great inland lakes were depositing material for ages during the whole of the middle and close of the palæozoic times. The same conditions but on an altered surface, still prevailed to a certain extent during the Permian times, for we see the oldest deposits of the incoming period deposited in wide and apparently open basins,—side by side with the basins of the palæozoic epochs. During the enormous periods of the Triassic and Rhætic times, when huge deposits of marine beds took place in the northern or Himalayan region, the same south-eastern pressure continued more or less, with the result of still more elevating and draining the peninsula, converting the lake-basins into great river valleys, at the same time depressing the Central Asian triassic sea, thus uniting the European (Alpine) with the Armenian (Asia Minor, Caucasus) with the Northern (Siberia) and Southern (Himalayan) basins, the deposits of which all show the most wonderful similarity of animal life which must have existed in those times.

Another link in the chain of evidences in this direction is the continuity of Mesozoic freshwater deposits of South and Central Africa, where we find the extensive Karoo series from the bottom boulder-beds (= Talchirs) to the topping sandstones of the Drakensberg mountains as nearly the same series, and containing similar species of fossil plants and terrestrial animals, as our own Gondwânas. Such an extensive rise of land may well correspond to a widespread triassic ocean extending over the north-western half of Asia and a great part of Europe.

After the deposition of the youngest members of the Rhætic or lower Lias, a change in the outline of the great southern continent takes place. Part of the present Indian ocean was formed, and the sea encroached along the western margin of the present peninsula, thus enabling the fluvatile deposits of the upper Gondwânas to mingle with the upper Jurassics of Cutch. Similar changes took place along the southern coast of Africa, *vide* the Jurassics of Uitenhage. Probably the great island of Madagascar is a standing monument of the former extent of the triassic continent of Gondwâna-Karoo type. Extensive sandstone deposits fringing the crystalline centre are described to occur in the island.

Indeed, the partial disturbance of post-Liassic times corresponds with the reported overlap of the upper Gondwânas (Mahadevas) over the older Gondwânas, and also with the absence in the Central Himalayan area of the Lower Oolite; on the lowest Liassic beds (which possibly belong really to the upper Rhætics) follow immediately the Spiti shales of upper-middle Oolitic age.

10. *The lower Trias in the marine and in the continental regions.*—Long ago attention was directed to the Triassic deposits of the Alps by the excellent works of the Austrian geologists, being remarkable as containing a singular admixture of Palæozoic forms of life with Mesozoic types. This is especially the case in the oldest Trias beds,—in the so-called Werfen beds, which lately have been divided

again into two sub-groups, both of which I recognized in the Himalayas. These base beds really represent the Buntsandstein of extra-alpine areas, but have a wide extent, being now known over a great part of Armenia, the Caucasus, probably Siberia, and certainly the Tibetan area. In a paper in this number of the Records I give short descriptions of a few new forms of Cephalopods from this bed, along with a fragmentary notice of its fossil contents generally. Besides all the principal fossils characteristic of the Werfen beds of the Eastern Alps, I found associated with them numerous parent forms of Ammonite genera, later on developed in the Trias, and also an undoubted *Productus*, which most resembles the *Productus latirostratus*, Howse, of the Permian. It is therefore a bed containing an admixture of palæozoic forms with younger types, but the intimate relation with the overlying Trias and Rhætic is well proved by the constant appearance of these variegated shales and limestones at the base of the Muschelkalk, overlapping in succession the various beds composing the Carboniferous formation.

Turning to the Peninsula, we find in like manner the base-rock of the Gondwânas, represented by the Talchirs with Karharbari beds, containing (according to Dr. Feistmantel, who was the first who drew attention to this fact), besides the forms later on so common in the Gondwânas, species closely allied to, if not identical with, the younger Carboniferous plants of Australia. If it is at all possible to compare marine beds with fresh water deposits, then surely the comparison between the "Werfen beds" of the Himalayas with the Talchir-Karharbari beds afford many points of analogy: both are the first deposits which take place after the readjustment of physical conditions in postpalæozoic times, and both contain a mixture of younger palæozoic and of triassic types of forms. I have, therefore, referred both these groups to the same parallel in the annexed table.

11. *The Tertiary series of the Tibetan Himalayas.*—The cretaceous limestones mostly occupy the last range of hills, forming as it were a rim around the vast high plateau of Tibet; beyond is a wide expanse of Tertiary rocks, beyond which appears again the mesozoic section. I only examined the series as far as the Sutlej, which river flows through upper Tertiary deposits.

Leaning against the cretaceous series of the Tibetan passes, I found white and red limestones, with a few indistinct traces and sections of Nummulites, the whole traversed by enormous dykes of a basaltic trap, which has completely altered the rocks into a kind of semi-metamorphic mass, in some parts resembling a porphyry. Stoliczka has described the same occurrence in the north-western Himalayas.

Next follow pepper-and-salt coloured sandstones and grits of molasse appearance, which in all probability represent some member of the southern Siwalik belt. But only here and there the highly inclined lower Tertiaries are seen in the lower river valleys, the whole being covered up by the younger gravels and sands which spread in horizontal beds and widely extended terraces over the great Sutlej valley. I may here mention that in this latter deposit near Dongpa I found fragments of mammalian bones, which makes it tolerably certain that the former finds of bones (Strachey) were also derived from the same source.

It is, therefore, clear that there was a break and change of physical conditions; 1st, after the deposition of the Rhætic; 2nd, after the close of the Nummulitic epoch.

12. *The Indian Peninsula during the cretaceous and tertiary epoch.*—*a.* The “breaking down” in shoals of the Indian ocean must have continued for a long period; at least the patches of Jurassics and later on of cretaceous beds which penetrated far into the northern half of the Peninsula go far to prove great fluctuations during these times. The presence of remains of a marine cretaceous formation in the south-east of the Peninsula and narrow strips of similar rocks in the Khasia hills, taken in connection with such formation in the Punjab, clearly demonstrates the existence of bays to have existed east and west of the Peninsula during those epochs. It was then that the enormous and long continued pressure coming from the south and now coming from two directions, squeezing as it were the triangular Peninsula forwards and northwards, resulted in the great dislocations of the Himalayan area, which were afterwards developed and widened. The pressure coming from both sides, east and west, resulted no doubt in the bow-shaped outline of the mountain ranges with its convexity near the centre and directed southwards, at the same time dislocating and shattering part of the western limits and thus forming the foundation stones to the later formed Salt-range and neighbouring hills,—west and south-west of the present strike of Himalayan hill-ranges. Simultaneously with this great tension, igneous rocks were pushed up in the dislocations formed; we find such examples in the Silhet Jurassic trap, in the admixture of trappean matter in the Olive-shales of the Salt-range, and the similar trappean-like cretaceous shales and rocks of Tibet.

b. The tension must have continued long after the close of the cretaceous epoch and during the deposition of the tertiaries, during which time the enormous dislocations have formed along the Southern Alps,—the west coasts of the Apennine chains, and here along the greater part of the southern limits of the Himalayas, and lastly along or parallel to the west coast (or somewhere near it), of India,—probably the opening through which the great basaltic flows found an exit, which, both in India and Africa, Arabia and the intervening ocean, play such an important part. Similar to the Mediterranean dislocation, the Indian one is also still the seat of volcanic agency.

It is probable that during the early tertiary times the present Himalayan area consisted of a series of long islands, not unlike the lines of islands now seen in the eastern Archipelago, between which the Nummulitics were deposited; I believe this feature was really owing to a partial breaking down of the area. The basaltic traps which we find in the tertiaries of both sides of the Indian Himalayan axis are met with along the strike of the dislocations.

In the following table I have endeavoured to render the comparison of rocks as above demonstrated:—

Comparative Table of Indian Formations.

HIMALAYAS.	PENINSULA.	SOUTH AND CENTRAL AFRICA.
Tertiary fresh water deposits.	Tertiary fresh water deposits.	Tertiary and recent formations.
Break.	Break.	Break.
Nummulites and trap. Cretaceous and trap.	Nummulites and trap. Cretaceous and trap (with inter-trappeans).	Cretaceous with trap.
Upper } Spiti shales Jurassic }	Mahadevas (Cutch, near coast-line).	Sandstones, &c., of the Drakensberg, and Uiten- hage Jurassics (coast).
Gap.	Overlap.	
Lias ... Lower Lias		
Rhætic { Upper Kössen beds Megalodon-limestones, &c. Kössen beds	Lower Gondwana series, (Barakars, Raniganj, and Panchets).	Karoo series.
Trias ... { Upper } Trias Middle } Lowest Trias (Alpine Werfen beds).	Talchirs.	... older beds.
Break.	Break.	Break.
Palæozoic rocks. { Carboniferous } Continuous group of rocks, Devonian } Lower Silurian } all fossiliferous. Upper Cambrian }	Vindhian sand- stones, &c. { Continuous group of sandstones, quartzites, &c., representing the whole of the post-Cam- brian Palæozoic rocks.	Table-mountain sandstone and quartzites.
Partial break.	Break.	Break.
Lower Cambrian slates and quartzites.	Lower Cambrian ? Sub-metamorphics, &c.	Devonian (marine) Silurian } much contorted. Slates, &c. }
Metamorphics.	Metamorphics.	Metamorphics.

PALÆONTOLOGICAL NOTES ON THE LOWER TRIAS OF THE HIMALAYAS, by C. L. GRIESBACH, F. G. S., *Geological Survey of India.*

Major-General R. Strachey, R.E., C.S.I., was the first to notice and describe¹ some of the grand sections through the Himalayas, and to draw attention to the existence in these snowy regions of triassic strata closely allied (as E. Suess has first shown)² to the Trias of the Eastern or Austrian Alps. As it has been my good fortune to have been sent to these lofty regions, I must here acknowledge the debt we owe to the learned General for having furnished such an excellent basis for further research in the most interesting region of the globe.

Having mapped the snowy ranges between the valleys of the Dhanli Ganga and Gori Ganga (Niti and Milam), I was able to collect a considerable material for description, but I must defer the detailed report on these noble sections, with maps, until after the next field season, when I hope to extend the survey to the frontiers of Nepál.

The great anticlinal fold of porphyritic gneiss with granite, termed by Stoliczka "Central gneiss" (by way of comparison with the so called "Central gneiss" of the Alps, a definition which has been given up long ago), is conformably overlaid by various metamorphic schists³ and these again by the Palæozoic and following formations, a brief description of which I have given in the companion paper in this number of the Records. I will therefore only mention that on the eroded surface of the carboniferous rises the huge mass of the triassic and Rhætic strata. The Rhætic beds form high, nearly perpendicular cliffs with an undercliff of older rocks, comprising the whole Trias from the Alpine Werfen beds (Buntsandstein) to the Upper Keuper rocks, all of which are well shown in the natural profile of Plate IV; the proportions of thicknesses and the outlines of the cliff are absolutely correct, being drawn with the aid of a camera lucida, from an opposite height, about in a horizontal plain with the junction of the Rhætic and Trias.

In the following list I give a detailed enumeration of the beds composing both the Rhætic and the Trias, with their probable correlations:—

Upper Oolite (Spiti shales).				THICKNESS.	
				Ft.	In.
Lower Lias	...	1. Black shales and "dark earthy limestone with oolitic structure, containing	...	13	0
Resembles the		<i>Belemnites bisulcatus</i> , Stol.			
Grestener beds of		" <i>tibeticus</i> , "			
the Eastern Alps.		" sp.			
		<i>Ammonites annulatus</i> , Sow. var.			
		" <i>darsei</i> , Sow.			
		<i>Rhynchonella austriaca</i> , Sss.			
		<i>Thalassites depressus</i> , Qu.			
		<i>Ostrea</i> , sp.			
		<i>Peeten</i> , sp.			
		Total	...	13	0

¹ Quart. Jour. Geol. Soc., Vol. VII, p. 292.

² Verh. Geol. Reichsanst. 1862, p. 258.

³ See Text illustration, fig. 1, of my paper in this number of the Records, p. 84.

		THICKNESS.	
		Ft.	In.
Rhætic	... 1. Grey crinoid limestone, very hard, weathering brown, thick-bedded, with intercalated shales, full of fossils, and in many places made up entirely of them. Containing a mixture of true Rhætic and Liassic forms: ...	13	0
Represents the Starhemberg facies of Kössen beds of the Alps.	<i>Pecten bifrons</i> , Salt.		
	„ <i>mayeri</i> , Winkl. (var.)		
	„ <i>lens</i> , Sow.		
	„ <i>corneus</i> , Gldfss. (non Sow.)		
	„ <i>cornatus</i> , Mün.		
	„ <i>valoniensis</i> , Deffr.		
	<i>Gervillia inflata</i> , Schl.		
	<i>Plagiostoma herrmanni</i> , Qu.		
	„ <i>giganteum</i> , Qu.		
	<i>Pholadomya roemeri</i> , Ag.		
	<i>Myophoria cardissoides</i> , Schl.		
	<i>Cardium rhæticum</i> , Mer.		
	<i>Terebratula horia</i> , Sss.		
	<i>Rhynchonella fissicostata</i> , Sss.		
Hauptlithoden-	2. Grey <i>Lithodendron</i> limestone showing sections of small shells on weathered surfaces ...	6	0
dron-limestone	3. Grey limestone with fossils as bed 1, and <i>Lithodendron</i> ...	5	0
of Suess:	4. Dark grey sandstone-like crinoid limestone with numerous white calc spar veins ...	9	6
	5. Uneven shaly beds similar to (4) ...	3	0
with Kössen	6. Dark grey crinoid limestone alternating with shaly beds ...	17	0
beds in follow-	7. Grey massive crinoid limestone ...	17	0
ing.	8. Sandstone-like limestone, false-bedded, here and there shaly ...	2	0
	9. Dark brecciated limestone with crinoids ...	1	6
	10. Very hard grey crinoid limestone with <i>Lithodendron</i> ...	5	6
	11. Flaggy beds of crinoid limestone ...	2	3
	12. Brecciated bed, made up of angular pieces of dark limestone with a few rounded pebbles; thins out rapidly ...	0	8
	13. Crinoid limestone, locally as (12) ...	3	0
	14. Dark crinoid limestone in irregular beds with white calc spar veins ...	13	0
	15. Grey dolomitic limestone in beds of about 1½" alternating with papery shales ...	2	6
	16. Dark grey sandstone-like crinoid limestone, top beds, shaly towards base, in thick masses ...	16	0
	17. Dark grey flaggy limestone (unfossiliferous) in beds of about 2" to 5", with shaly partings ...	7	0
	18. Brown shaly sandstone thinning out ...	0	5
	19. Flaggy limestone, vertically jointed ...	9	3
	20. Uneven sandstone bed	0	6
	21. Grey calcareous sandstone } with thin shaly	0	6
	22. Grey limestone } partings.	0	9
	23. Grey calcareous sandstone }	0	6

			THICKNESS.	
			Ft.	In.
24.	Grey limestone flags with shaly partings	...	2	0
25.	„ friable shales	...	0	6
26.	„ limestone	...	0	9
27.	Friable grey needle-shales	...	0	2
28.	Grey limestone in massive beds with a few thin partings of shales	...	7	0
29.	Dark grey needle-shales, thin out and pass into limestone	...	1	2
30.	Thin flaggy limestone beds	...	0	6
31.	Dolomitic limestone	...	0	8
32.	Shaly limestone	...	2	4
33.	Crinoid limestone with some fossils (Kössen type)	...	1	0
34.	Sandy shales	...	1	8
35.	Crinoid limestone	...	0	5
36.	Papery sandy shales	...	0	2
37.	Brown calcareous sandstone (fossils)	...	0	7
38.	Crinoid limestone	...	0	4
39.	Shaly „	...	1	2
40.	„ and papery calcareous beds	...	1	3
41.	Grey limestone	...	0	3
42.	Sandy shales	...	0	3½
43.	Crinoid limestone	...	1	0
44.	Papery calcareous shales	...	0	2½
45.	Sandstone shales	...	0	5
46.	Shaly crinoid limestone	...	0	8
47.	„ and flaggy crinoid limestone	...	2	0
48.	Grey calcareous sandstone	...	0	4
49.	Shales	...	0	2
50.	Grey crinoid limestone	...	0	7
51.	Sandy shales	...	0	5
52.	Papery marly shales	...	0	10
53.	Grey limestone with shaly partings	...	0	10½
54.	Friable limestone shales	...	1	0
55.	Marly bed	...	0	8
56.	Irregular bed of grey limestone; thins out	...	1	3
57.	Flaggy limestone with shales	...	6	9
58.	Grey crinoid limestone with <i>Belemnites</i>	...	0	5
59.	Limestone flags with friable shales	...	4	0
60.	Crinoid limestone with <i>Pecten bifrons</i> , Salt	...	1	4
61.	Limestone flags and shales	...	2	4
62.	Shaly calcareous sandstone	...	2	9
63.	Crinoid limestone with a shaly parting	...	1	9
64.	„ „ with <i>Pecten bifrons</i> , Salt	...	3	0
65.	Dark limestone alternating with shaly crinoid beds	...	4	0
66.	„ grey limestone, dolomitic, with shaly partings	...	35	0
67.	„ fossiliferous crinoid limestone in massive beds	...	45	0
Dachstein lime- stone.	} 68.	Grey earthy limestone full of <i>Myacites</i> sp.	7	0
		69. Hard limestone beds, containing many fossils, and on the weathered surfaces showing sections of large <i>Megalodon</i> sp.	35	0

		THICKNESS.	
		Ft.	In.
	70. Hard crinoid limestone in thicker beds ...	7	6
	71. Dolomitic limestone ...	6	0
	72. „ „ in flaggy beds ...	3	6
	73. Massive grey dolomite, towards base rather flaggy	45	0
Hauptdolomit ...	74. „ dolomite, with scarcely any bedding ...	135	0
	75. As (74), but with partings of crinoid limestone ...	223	0
	76. Dolomite in beds of about 4 feet thickness towards base, reddish, and containing <i>Lithodendron</i> ...	98	0
	77. Dark concretionary limestone with reddish purple cellular Rauchwacke appearance here and there, in beds of 6 inches to 1 foot ...	5	0
	78. Crinoid limestone in thicker beds ...	11	0
Plattenkalk of Gumbel. {	79. Dark dolomites in massive beds, the contact surfaces knitted together (resembling sutures, in the outcrop) ...	100	0
	80. Dolomites and limestone beds with "knitted" contact surfaces as (79), full of <i>Lithodendron</i> , and with a few shaly partings ...	48	0
	81. Massive beds of dark blue limestone and dolomite alternating with flaggy beds of limestone; the latter form about 12 feet of the upper part. Some masses of it of dark purple colour with crinoid sections ...	50	0
	82. Dark dolomites with calcspar veins ...	147	0
	83. „ „ flaggy beds and partings of shaly sandstone ...	241	0
	84. Dark hard concretionary limestone alternating with dolomitic beds ...	74	0
	85. Grey and reddish dolomites in perfectly inaccessible cliffs, about ...	700	0
TOTAL ...		2,200	7½

As I intend to give here only a short description of the lowest members of the Trias, I will only say so much, that in the main the above Rhætic section corresponds exactly with the typical sections of that formation in the Austrian Alps, namely, we have here in descending order:—

1. *Lithodendron*-limestone, interbedded with limestone containing fossils belonging to the Alpine Kössen beds, which have been grouped into four horizons by Suess=Hauptlithodendronkalk with Kössen beds.
2. Thick-bedded limestones, here and there dolomitic, still with *Lithodendrons* here and there, and beds with *Megalodon*=Dachsteinkalk.
3. Great development of dolomites and flaggy limestones=Hauptdolomit with Gumbel's Plattenkalk.

The undercliff consists of a series of beds which represent the whole of the marine Trias beds of the Eastern Alps. The series rests on the denuded and rugged carboniferous quartzites, which again form a steep cliff falling almost vertically down to the base of the valley.

The detailed section of it is as follows :—

		UPPER TRIAS.		THICKNESS.	
				Ft.	In.
Alps :	... 22.	Compact brown (liver-coloured) limestone, with rough contact surfaces; beds nearly of equal thickness, about 12 inches, and here and there separated by greenish-grey shales. Numerous bivalves, closely allied to ...		152	0
Opponitzer beds.		<i>Corbis mellingi</i> , Hau. var.			
	21.	Liver-coloured brown limestone, alternating with greyish-green shales, containing ...		29	0
		<i>Corbis mellingi</i> , Hau. var.			
		<i>Orthoceras</i> , sp.			
	20.	Earthy limestone with shaly partings ...		228	0
	19.	Shaly limestone with earthy shales alternating ...		30	0
Alps :		<i>Spirifer lilangensis</i> , Stol. var.			
Lunzer and Partnach beds.	18.	Shaly limestone and shales with hard concretionary limestone ...		22	0
	17.	Greenish-grey shales ...		4	6
	16.	Limestone with chert nodules ...		1	6
	15.	Flaggy limestone ...		5	0
	14.	Friable greenish-grey shales, weathering brown, with flaggy limestone alternating ...		31	0
	13.	Marly friable shales ...		5	0
Alps :	... 12.	Hard grey limestone ...		4	0
Hallstadt beds.	11.	Hard grey limestone, weathering brown, rather silicious, containing nodules of white concretions with fossils :			
		<i>Opis globata</i> , Dtn.			
		<i>Acrochordiceras spinosens</i> , Hau.			
		<i>Tropites ehrlichi</i> , Hau.			
		var. <i>Feistmanteli</i> , n. sp.			
		<i>Balatellites himalayanus</i> , Blfd.			
Alps :	... 10.	Grey earthy limestone beds, with marly and shaly partings, weathers brown.			
St. Cassian.	9.	Same as (10) with			
		<i>Spirigera</i> , sp.			
		9, 10, and 11, total ...		275	0
	8.	Greyish-green micaceous shales, a few plant impressions ...		160	0
	7.	Shaly grey earthy limestone ...		38	0
Alps :	... 6.	Dark splintery limestone flags with dolomitic beds and very scarce partings of black shales ...		76	0
Wengen beds and St. Cassian.	5.	Black limestone beds in flags of about 6 inches thickness, which form groups of about 3 feet thickness, alternating with the same thickness of black splintery shales, with ...		152	0
		a species of the group of the			
		<i>Amaltheidæ</i>			
		<i>Halobia rarestriata</i> , Mojs.			
		<i>Daonella tyrolensis</i> , Mojs.			
		" sp.			

						THICKNESS.		
						Ft.	In.	
Alps :	...	4.	Delomitic limestones in more massive beds, with few shaly partings			...	38	0
	
Wengen beds.	...	3.	Shaly limestone with—			...	38	0
		<i>Daonella</i> , sp.						
<i>Spirifer lilangensis</i> , Stol. var.								
Alps :	...	2.	Thick-bedded shaly limestone with traces of fossils, mostly Ammonites			...	48	0
	
Buchenstein beds.	...	1.	Black limestone flags of about 12 inches thickness, each alternating with black splintery shales of same thickness			...	103	0
	

LOWER TRIAS.

						Ft.	In.
II. VIRGLORIA LIMESTONE.	{	b.	Reifling limestone (Alps).	122.	Very hard grey concretionary limestone in massive beds with subordinate partings of dark shales containing many fossils very difficult to extract :	about	50 0
						<i>Oethoceras dubium</i> , Hau.	
						<i>Trachyceras voiti</i> , Opp.	
						" <i>thulleri</i> , Opp.	
						" sp.	
						<i>Arcestes difissus</i> , Hau.	
						<i>Ptychites gerardi</i> , Blfd.	
						<i>Pinacoceras floridum</i> , Wulf.	
						<i>Pecten</i> , sp.	
						<i>Myacantha</i> , sp.	
						<i>Pleurotoma sterilis</i> , Stol.	
						<i>Reptilian bones</i> .	
		a.	Recoaro-limestone (Alps).	121.	Earthy-grey limestone, towards base somewhat shaly :	...	3 0
						<i>Rhynchonella semiplecta</i> , Mün., var. }	
						" <i>salleriana</i> , Stol. }	
I. WERFEN BEDS	{	b.	Campiler beds (Alps).	120.	Hard grey splintery limestone	...	0 3
						119. Dark friable clayshales, weathering variegated	
						...	
						118. Limestone	
						...	
						117. Limestone with shaly partings	
						...	
						116. Limestone	
						...	
						115. Shales	
						...	
						114. Limestone	
						...	
						113. Shales alternating with 12 thin beds of limestone	
						...	
	{					112. Limestone	
						...	
						111. Shales	
						...	
						110. Limestone	
						...	
						109. Shales with limestone partings	
	{					...	
						108. Limestone	
						...	
	{					107. Shales, alternating with 11 limestone partings	
						...	

				THICKNESS.	
				Ft.	In.
	106. Limestone ...	...	...	0	8
	105. Shales ...	...	...	0	10
	104. Limestone ...	...	...	0	6
	103. Shales with 5 limestone partings ...	...	...	0	11
	102. Limestone ...	...	...	0	5
	101. Shales ...	...	...	0	7
	100. Limestone ...	...	...	0	7½
	99. Shales ...	...	...	0	6
	98. Limestone ...	...	...	0	7
	97. Shales and limestone partings ...	...	...	1	2
	96. Limestone ...	...	...	0	8
	95. Shales ...	...	...	0	7
	94. Limestone ...	...	...	0	4
	93. Shales ...	...	...	0	7
	92. Limestone ...	...	...	0	9
	91. Shale with 10 limestone partings ...	...	...	1	4
	90. Limestone ...	...	...	0	7
	89. Shales and limestone partings ...	...	...	0	10
	Salt-range: Zone of <i>N. planulatus</i> , DeKon.				
	88. Limestone ...	...	...	0	6
	87. Shales with limestone parting ...	...	...	0	1
	86. Limestone ...	...	...	0	2
	85. Shales with 2 limestone partings ...	...	...	0	8
	84. Limestone ...	...	...	0	5
	83. Shales ...	...	...	0	3
	82. Limestone with one shaly parting ...	...	...	0	4
	81. Shales with two limestone partings ...	...	...	0	6
	80. Limestone ...	...	...	0	3
	<i>Monophyllites wetsoni</i> , Opp.				
	79. Shales ...	...	...	0	5
	78. Limestone ...	...	...	0	5
	77. Limestone with three shaly partings ...	...	...	0	6
	76. Limestone ...	...	...	0	5
	75. Limestones with 17 shaly partings ...	...	...	1	7
	74. Shales ...	...	...	0	2
	73. Limestone ...	...	...	0	6
	72. Shales ...	...	...	0	½
	71. Limestone ...	...	...	0	2
	70. Shales with ...	...	...	0	1½
	<i>Ophiceras tibeticum</i> , n.s.				
	69. Limestone ...	...	...	0	½
	68. Shales ...	...	...	0	2
	67. Limestone ...	...	...	0	1
	66. Shales ...	...	...	0	1
	65. Limestone ...	...	...	0	1
	64. Shales ...	...	...	0	1
	63. Limestone ...	...	...	0	4
	62. Shales ...	...	...	0	½
	61. Limestone ...	...	...	0	1
	60. Shales ...	...	...	0	2
	59. Limestone ...	...	...	0	3
	58. Limestone with 6 shaly partings ...	...	...	0	6
	Salt-range: zone of <i>Ophiceras lyellianum</i> , DeKon.				

I. WERFEN BEDS.
—contd.

I. WERFEN BEDS.
—contd.

				THICKNESS.	
				Ft.	In.
57.	Limestone	...	...	0	2
56.	Shaly limestone	...	...	0	1½
55.	Shales	...	...	0	1
54.	Limestone with 2 shaly partings	...	...	0	5
53.	Limestone with shales	...	...	0	3
52.	Limestone	...	...	0	5
51.	Shales	...	...	0	½
50.	Limestone	...	...	0	1
49.	Shales and limestone	...	...	0	2½
48.	Shales	...	...	0	2½
47.	Limestone	...	...	0	3
46.	Shales	...	...	0	2
45.	Limestone	...	...	0	2½
44.	Shales	...	...	0	1
43.	Limestone	...	...	0	3
42.	Shales with a thin bed of limestone	...	...	0	5
41.	Limestone with 9 shaly partings	...	...	1	3
40.	Limestone	...	...	0	1
39.	Limestone	...	...	0	3
38.	Limestone with 14 shaly partings	...	...	1	2
37.	Limestone	...	...	0	2½
36.	Shales	...	...	0	2
35.	Limestone with shaly partings	...	...	0	3½
34.	Shales	...	...	0	1
33.	Limestone with 3 shaly partings	...	...	0	5
32.	Shales	...	...	0	2
31.	Limestone	...	...	0	2
30.	Shales	...	...	0	3
29.	Limestone	...	...	0	2½
28.	Shales	...	...	0	2
27.	Limestone	...	...	0	1½
26.	Shales	...	...	0	1½
25.	Limestone	...	...	0	1
24.	Shales	...	...	0	1½
23.	Limestone	...	...	0	2
22.	Shales	...	...	1	0
21.	Limestone	...	...	0	3
20.	Shales	...	...	0	1
19.	Limestone	...	...	0	3
18.	Shales	...	...	0	4
17.	Limestone	...	...	0	3
16.	Shales	...	...	0	10
15.	Limestone with shaly partings	...	...	1	6
14.	Limestone	...	...	0	6
13.	Shales	...	...	1	0
12.	Limestone	...	...	0	3½
11.	Shales with 11 thin layers of hard splintery limestone	...	...	0	4½
10.	Limestone	...	...	0	3
9.	Shales with limestone (1') towards top with—	...	...	5	0

Otoceras woodwardi, n.s.

				THICKNESS.	
				Ft.	In
	8. Limestone ...	...	...	0	2
	7. Shales ...	...	...	0	5½
	6. Limestone with—	...	...	0	3
	<i>Xenodiscus gangeticus</i> , DeKon.				
	" <i>buchianus</i> , "				
Salt-range, zone of <i>Pty-</i>	5. Variegated papery shales	...	...	0	6
<i>chites lawrencianus</i> ,	4. Limestone with —	...	...	0	4
DeKon.	<i>Aracula venetiana</i> , Hau.				
<i>Xenodiscus demissus</i> .	<i>Myophoria orata</i> , Br.				
" <i>gangeticus</i> .	<i>Posidonomya angusta</i> , Hau.				
	<i>Otoceras woodwardi</i> , n.s.				
	<i>Xenodiscus demissus</i> , Opp.				
	" <i>gangeticus</i> , DeKon.				
	3. Friable, papery shales with a parting				
	of limestone (1") with—	...	...	0	9
	<i>Otoceras woodwardi</i> , n.s.				
	2. Dark grey limestone with shaly layers				
	with—	...	...	0	5
	<i>Posidonomya angusta</i> , Hau.				
	<i>Gervillia mytiloides</i> , Schlot.				
	<i>Modiola triquetra</i> , Seeb.				
	<i>Myophoria orata</i> , Gdfss.				
	<i>Aracula venetiana</i> , Hau.				
	<i>Bellerophon</i> , sp.				
	<i>Nautilus brahmanicus</i> , n.s.				
	<i>Otoceras woodwardi</i> , n.s.				
	" " var. <i>undulatum</i> , n.s.				
	<i>Ptychites lawrencianus</i> , DeKon.				
	<i>Opliceras medium</i> , n.s.				
	" <i>himalayense</i> , n.s.				
	" <i>tibeticum</i> , n.s.				
	" <i>densitesta</i> , Waag., var.				
b. Campiler beds ...	<i>Xenodiscus gangeticus</i> , DeKon.				
(Alps).	" <i>buchianus</i> , "				
	" <i>demissus</i> , Opp.				
	<i>Trachyceras gibbosum</i> , n.s.				
a. Sciss beds (Alps) {	1. Dark, carbonaceous, crumbling shales,				
Salt-range Productus	micaceous, weathering in reddish and				
beds.	deep-brown tints, giving it a variegat-				
	ed appearance, with a few thin beds of				
	hard grey limestone. The general				
	character of these shales is the same				
	as of all the intercalated beds of				
	shales of the beds above	...	127½		
	It yielded—				
	<i>Mo. otis clarae</i> , Emmr.				
	<i>Productus latirostratus</i> , Howse, var.				
	<i>Arcestes</i> sp.				

The whole rests on the carboniferous series.

The above list of beds, it will be seen, corresponds in a marvellous degree with the beds of the Trias as developed in the Eastern Alps, and the order stands therefore as follows:—

The Trias in the Himalayas.

	Character of rocks.	Zones.	Correlation with horizons in the Eastern Alps.	Trias in Germany.
UPPER TRIAS.	6. Liver-coloured limestone with greenish shales.	<i>Corbis mellingi</i> , Hau. var.	} Opponitz and Raibl.	} Keuper.
	5. Friable shales and earthy beds.	<i>Spir. lilangensis</i> , Stol.		
	4. Limestone	<i>Tropites ehrlichi</i>	Hallstadt and	
	3. Earthy beds and shales	.....	St. Cassian.
	2. Black limestone and dolomites.	<i>Daonella tyrolensis</i> , Mojs.	Wengen.	
	1. Black limestone flags and splintery shales.	Brachiopods	Buchenstein.	
LOWER TRIAS.	4. Hard grey concretionary limestone.	<i>Ptychites gerardi</i> , Blfd.	Reifling limestone.	} Virgloria limestone } Muschelkalk.
	3. Earthy limestone	<i>Rhynchonella semiplecta</i> , Mün., var.	Recoaro limestone.	
	2. Limestone and shales.	<i>Posidonomya angusta</i> , Hau.	Campiler beds	} Werfen beds } Buntsandstein.
	1. Dark shales, etc.	<i>Monotis clarae</i> , Emm.	Beds of Seiss	

As far as is known at present, this succession of horizon holds good in India over a considerable area, to judge from certain beds, which have been found in other parts of our Himalayas. The lower group has been described by Stoliczka from the north-west Himalayas (Spiti), but he considered only the upper part of the Lower Trias as such, with *Rhynchonella salteriana*, Stol., and *Ptychites gerardi*, Blfd. He certainly came across the lower group, but in the absence of known Trias fossils he represented it as upper carboniferous, containing numerous *Productus semireticulatus*, Mart. (sp.), *Spirifer rajah*, Dav. I have compared some of his original specimens with my own collection, and have no doubt that the beds are quite identical both in lithological character and probably in their fossil contents.

It might be urged that the presence of the *Productus* speaks for a Permian age of these deposits; but taking into consideration the fact that stratigraphically the complex of Trias beds is a connected series of deposits without any interruption, with the greyish black shales invariably at their base, the whole resting on

a rugged and denuded surface of the carboniferous quartzite, it must be admitted that on this account alone the shales (Kuling shales of Stoliczka) must be included amongst the Triassic group. These shales resemble the Werfen beds of the Alps, not only in lithological character, but also in the fact that here as there they contain a number of older forms of life side by side with new arrivals. Such is, it appears, the case with the Werfen beds of Armenia¹.

The following forms of the 1st and 2nd groups of the lower Trias are identical with such of the Werfen beds of the Alps:—

Monotis clara, Emm.
 „ *angusta*, Han.
Gervillia mytiloides, Schl.
Modiola triquetra, Seeb.
Myophoria ovata, Gdf.
Aricula venetiana, Hau.

Nearly identical with a Hallstadt form is *Ophiceras* (Amm.) *densitesta*, Waag.²

All the other species represent earlier stages of forms found also in the triassic beds of the Eastern Alps.

So for instance:—

Otoceras woodwardi allied to { *Hungarites* (?) *Strombecki*, Griep.
 „ *scaphitiformis*, Hau.
 „ *zalaensis*, Bökh.

Ophiceras tibeticum, n.s., allied to *Lytoceras simonyi*, Hau., and other *Lytocera-*
tites, occurring in the Lower Trias.

DESCRIPTION OF NEW SPECIES.

Class : CEPHALOPODA.

Order : TETRABRANCHIATA.

Family : NAUTILIDÆ

Genus : NAUTILUS.

NAUTILUS QUADRANGULUS, Beyr., var. BRAHMANICUS, n. s. Plate I, figs. 1—3.

This species is most nearly allied to the Liassic forms, of which *N. aratus*, Schl., is the representative. The shell is considerably involute, the umbilicus deep. The ventral side flattened, the section of the shell sub-angular. The descent to the umbilicus is vertical and sharply defined. Five radial lines of growth are visible, and a few broad indentations at intervals of about $\frac{3}{8}$ inch along the last chamber indicate a faint kinship of this form to *Nautilus fugax*, Mojs.³ Towards the mouth the shell opens out, trumpet-shaped. What remains of the last

¹ Abich: Geol. Forschungen in den Kaukas. Ländern, 1st. Theil, Wien, 1878.

See also Mojsisovic's Verh. Geol. Reichsanst., 1879, p. 171.

² Benecke's Geog. Pal. Beiträge, I, p. 369.

³ Jahrb. k. k. Geol. Reichsanst., 1869, Pl. XIX, fig. 3.

chamber amounts to exactly one-half of the entire evolution. Siphon situated at about $\frac{2}{3}$ of the height (fig. 3). The septa show nearly the same lines as *Nautilus subaratus*, Keys.;¹ the pointed antisiphonal lobe marks this species at once as belonging to the forms of which *N. aratus*, Schl., is the type. The number of septa are about thirty in a whorl.

The only character which distinguishes this species from Beyrich's species *N. quadrangulus*² is the fact, that the German Muschelkalk form seems more compressed than our species, so far as I can judge from the figure given. But there can be no doubt that the German Muschelkalk species is a descendant of this lowest Trias form.

Likewise *Nautilus spitiensis*, Stol., is probably also only a later stage of development of this species, which is common in the Werfen horizon of the Tibetan Himalayas.

With the exception of the angular shape of the section of the whorls which is so marked in the Indian species, it agrees very nearly with *Nautilus subaratus*, Keys., both in general shape and course of the lobe line. In fig. 2 I have shown another specimen, which I cannot separate at present from the larger form in spite of the indication of a hexagonal outline of the section of the mouth as shown in the figure. It is probably only a younger individual of the same species.

It is very numerous in Bed 2 (horizon of *Posidonomya angusta*, Hau.) of the lowest Trias.

Class: CEPHALOPODA.

Order: ?

Family: AMMONITIDÆ.

Tribe: PINACOCERATIDÆ.

Genus: OTOCERAS, n. g.³

Amongst the numerous forms found in Bed 2 (horizon of *Posidonomya angusta*, Hau.), one of the most remarkable groups is that for which I propose the above name. Occurring, as they do, in a bed belonging to the lowest Trias, they form the connecting link of a group of forms, the first of which appear in the palæozoic epoch.

The earliest species belonging to the tribe of *Pinacoceratidæ* appear in the Devonian, where we find the *Sagecceras sagittarius*, Sandb.

In the Permian of Armenia we find again several species, and representatives of it are found in India (Salt-range) and pass on into Upper Trias, where many species belong to that genus.

The species described under the above generic name appear in the lowest Trias as companions of a number of early Triassic types, in the same bed with

¹ Middendorff's Reise in Sibirien, Pl. IV, fig. 3.

² Abh. Akademie, Berlin, Pl. III, fig. 5.

³ *Oūs, ὠτος* = ear.

Pos. angusta, Hau. Though it seems that there are several varieties, if not species, amongst the numerous specimens obtained, I prefer to include them for the present under one collective name.

OTOCERAS WOODWARDI, nov. spec. Plate I, figs. 4 & 5, and Plate II.

Shell involute, with very deep umbilicus, with rapidly increasing outer whorls. The part of the shell nearest the umbilicus bulged out into an ear-like shape, giving the section of the shell (Plate I, fig 4a,) a more or less rhomboidal aspect.

It is very probable that the last whorl in adult individuals covered and enclosed the entire shell. In all the specimens which I collected there is a tendency to enlarge the latter whorls at the expense of the umbilicus. The sides of the shell are only slightly curved and slope towards the sharp knife-like siphonal side enclosing an angle of about 67°. The compressed siphonal side is one of the most characteristic features of this species. In one of the adult specimens (Plate I, fig. 4), this part of the shell has quite the appearance of a sharp knife, and only a faint indication of a three-edged termination is visible, whereas in some of the younger specimens (Plate II, figs. 1 and 3) and even in the older form (Plate II, fig. 2a) the tripartite character of the siphonal side is strongly marked. This character alone would stamp this species as belonging to *Hungarites*, Mojs.,¹ of which *H. scaphitiformis*, Hau.,² and *H. zaluensis*, Böckh.,³ are the types, but the shape of the ear-like prolongation of the sides of the shell near the region of the second side-lobes is a character entirely absent in the Austrian genus. A line connecting the ear-like prolongations of the sides, or, in other words, the second side-lobes, will intersect the median plane in a point, from which to the siphonal margin of the preceding whorl is about the third of the entire distance between the point of intersection and the siphonal margin of the outer shell. A vertical projection of the inner margin of the first lateral saddle to the median plane will intersect that plane in the siphon of the preceding whorl.

From Plate I, fig. 4a, it will be seen that the proportion in the increase of lateral expansion of the last whorl increases rapidly at the expense of the increase to the height of the shell, and it is not at all improbable that, as I said above, the final chamber inclosed nearly the whole of the shell in adult specimens, which character is indicated in fig. 3 of Plate II, which shows the almost vertical sides of the umbilicus, but since drawing the plates I have worked out of some blocks of stone the fragment of a larger specimen, showing part of the last chamber with the umbilicus. The latter is very narrow and closing in towards the outer side. The shell is extremely thick near the ear-like prolongation in the umbilical region and covered with wrinkles. The shell is covered with fine wavy lines of growth S-shaped, slightly bent forward near the siphonal margin.

The lobes show some variation, mainly in the auxiliary ones, but these increase in number with the successive whorls in the same specimen. As shown in

¹ Verh. Geol. Reichsanst., 1879, p. 140.

Denksch. Akademie Wiss., Wien, 1855, Pl. III, fig. 4.

³ A. M. K. Földtani intézet, Pest, 1872, Pl. VII, figs. 1 and 2.

the drawings of lobes in Plate II, this species possesses a broad siphonal lobe ending on both sides of the semicircular siphonal saddle in a sharp point. The external saddle (fig. 1b) is moderately high and a little narrower than the siphonal lobe. The first lateral lobe is the deepest of all, of the same width as the external saddle, and at the base shows plainly a tripartite arrangement of the serration.

I remarked also that the corresponding lobes vary on each side of the specimen (fig. 1). Whilst the first lateral lobe of the left side shows plainly this tripartite arrangement of serration, those on the right side have an additional sharp point added to the lower margin of the lobe as shown in fig. 1b. The larger specimen, fig. 4, shows a still more complicated serration of this lateral lobe, similar also in figs. 3 and 5. There follows in all specimens a very large first lateral saddle, slightly bent towards the inner side, with following rather narrow second lateral lobe, serrated at the base, this serration varying in the different specimens. The second lateral saddle is only half as high as the first and great lateral saddle, rather wider in proportion to its height, and followed by one or two auxiliary lobes of varying course. In some specimens the first auxiliary lobe reaches only half down the rounded and broad second lateral saddle and is not serrated at the base and might be described as a rudimentary lobe; in others, figs. 2b, 4 and 6, the auxiliary lobes and saddles are similar in shape to the last lateral lobe and saddle, decreasing in size as they near the ridge (r), noticed above. Beyond this the sutural line runs in a series of rudimentary lobes and saddles to the sutural margin (s), where it forms a flat serrated lobe; on the antisiphonal side I noticed on prepared specimens (fig. 6) a saddle, as broad as high, sloping towards the margin (s) followed by a narrower but deeper lobe, serrated at base, and a second higher and wider saddle, similarly sloping towards the marginal side. The antisiphonal lobe is bipartite.

Locality.—South of Rimkin Paiar and north of Kiunglung encamping ground, head-waters of the Ganges river.

OTOCERAS WOODWARDI, var. UNDATUM, n. s. Plate I, fig. 5.

With the first described specimens and only at one locality were found a few individuals agreeing in general shape and lobes with *Otoceras woodwardi*, but, unlike even the larger specimens of this species, showing very marked wavy ribs, only very slightly bent forward near the siphonal margin, but swelling out near the middle of the side of the shell. As none of the other specimens show this character, I have thought best to separate it for the present as a variety of the other form.

Locality.—South of Rimkin Paiar, east slope of the Kurgudthidhar mountain.

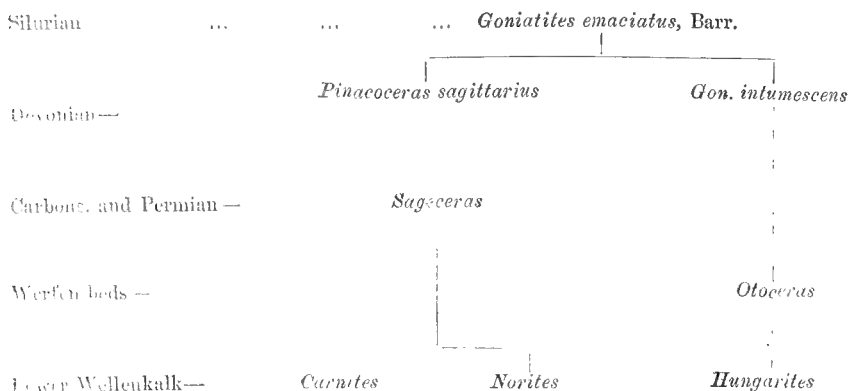
Allied forms.—The ancestors of the forms above described must be sought for in the family of the *Pinacoceratidae*, Mojs., the oldest known ones of which occur in the Devonian of Oberscheld, *Pinacoceras sagittarius*, Sandb.¹ That *Sageceras*, known from the Permian and which like *Pinacoceras* lived up to the

¹ Sandberger: Schichtensystem in Nassau, p. 77.

Upper Triassic times, is a descendant from *Pinacoceras* is probable. There is another form which bears close resemblance to *Otoceras*, *Goniatites intumesens*, Bey.¹ var. *acutus*, which is a close relation of it and belongs to the Devonian system. In external shape, thickness of shell, fine lines of growth and the sharp-edged siphonal margin, they are all but identical, and from the figure (1a) it seems as if this species also, in a rudimentary stage, possessed the ear-like prolongations of the shell near the umbilical region. Turning to the lobes we find also the first lateral saddle largely developed and turned towards the umbilicus, and an indication of a second lateral saddle, but the lobes terminate in simple sharp points only, though corresponding in general proportion. The line of projection of the preceding siphonal margin (vertical to the median plane) cuts through the second lateral lobe near the inner margin of the great first saddle. We have here the true predecessor of *Otoceras* in Devonian beds.

The next younger form known is *Hungarites* (*Ceratites*) *strombecki*, Griep.² from the lowest Wellenkalk of Brunswick, which shows many characteristics of my genus, but most so in the form of the lobes (fig. 3) which are nearly identical with mine. Apparently also the projection of the siphonal margin of the preceding whorl passes through the second lateral lobe.

Whether the genus *Hungarites*³ is a further development of *Otoceras* is not quite clear to me, but the description of the lobes given by J. Böckh⁴ seems to point to a relation with the older form of *Otoceras*. Mojsisovic⁵ hints at the possible derivation of *Pinacoceras* from *Goniatites emaciatus*, Barr.,⁶ and indeed this species shows even greater likeness in general form and arrangement and position of the lobes to *Goniatites intumesens*, Bey., so that there is the indication of a pedigree, which would stand thus :



¹ Sandberger's Verst. Rhein. Schichtensyst., Taf. VII, fig. 1.

² Zeitsch. Deutsch. Geol. Gesellsch., Taf. VII.

³ Verh. Geol. Reichsanst., 1879, p. 140.

⁴ Földtani intézet, 1873, p. 156.

⁵ Abh. Geol. Reichsanst., Bd. VI, p. 43.

⁶ Syst. Sil., Vol. II, Pl. III.

PTYCHITES LAWRENCIANUS, DeKon.: Quart. Journ. Geol. Soc., Vol. XIX,
Pl. VI, fig. 3.

As such I determine a few not well preserved specimens. They agree very well in general shape and in the formation of lobes with the Salt-range species, but with this exception, that my specimens exhibit traces of an ear-like ridge near the umbilical margin, thus showing some kinship to *Otoceras woodwardi*. Further researches in the Himalayas may reveal better specimens.

Of older forms the most nearly allied are *Goniolites heninghausi*, Von Buch,¹ *G. intumescens*, Bey., var. *intermedius*, Sandb.,² and *G. buchii*, Vern.,³ thus showing in some degree a derivation from the early types of *Otoceras*, and itself representing a predecessor of the later *Ptychites* forms of the Muschelkalk.

Genus: NORITES.

NORITES PLANULATUS, DeKon., var.: Quart. Journ. Geol. Soc., Vol. XIX,
Pl. V, fig. 1.

My species differs somewhat from DeKoninck's figure, in that the ribs on the sides of the shell are more strongly marked and seem indeed to form tuberculous masses; the siphonal part is perfectly flattened and resembles in that *Norites gondola*, Mojs. This species is common in the higher beds (89) of the Campiler group of the lower trias.

There is an excellent predecessor to this species found in *Goniolites tenuistriatus*, Vern.⁴

Tribe: LYTOCERATIDÆ.

Genus: OPHICERAS.⁵

Under this generic name I propose to unite forms which possess the external characters of the *Lytoceratidæ*, but possess a much simpler lobe-line even than *Monophyllites*, and must be considered as an older stage of development of the *Lytoceratites*, which appear first in the Muschelkalk. For the description of the generic characters I refer to *Ophiceras tibeticum*, n. s., which may be looked upon as the type of my genus.

OPHICERAS TIBETICUM, n. sp. Plate III, figs. 1 to 7.

Shell compressed, section of whorls oval and widening near the umbilicus (see figs. 2 and 3); the latter large and shallow. The shell with seven to nine whorls, each covering a little more than a third of the preceding one. The shell is thick, especially so near the umbilicus, and covered with fine wrinkles or lines of growth S-shaped and bent forward near the siphonal side (figs. 4 and 5). In the body-chamber, they assume the character of fine S-shaped ribs (fig. 6), resembling in that stage the ribs of *Lytoceras simonyi*, Hau., with which species my form corresponds in many characters. At irregular intervals the shell swells into rounded bumps, largest near the umbilical margin. The siphonal side is rounded,

¹ Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXV, fig. 7.

² Rhein. Schicht. Syst., Pl. VII, fig. 2.

³ Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 1.

⁴ Trans. Geol. Soc., Vol. VI, 2nd Ser., Pl. XXVI, fig. 7.

⁵ *Ophis* = serpent.

and the wrinkles or folds run across it and join with those of the other side. In a larger fragment of a body-chamber, which I refer to this species (fig. 1), the back is smooth, and the wrinkles or folds show only near the umbilical side.

The lobes are simple; the projection of the preceding whorl intersects the second lateral lobe near the outer wall of the second lateral saddle; the siphonal lobe is much wider than high, with a moderately high siphonal saddle, separated by the siphon. The external saddle is about as high as wide. The first lateral lobe is very deep and narrow, followed by a high first lateral saddle, bent inwards. The second lateral lobe is narrow and reaches only half as low as the first one. The second lateral saddle resembles in shape and height the first one, followed by a lobe of about the same depth as the last one, situated at the umbilical margin. The internal sutures are very simple. A deep bipartite antisiphonal lobe is accompanied by a rounded low saddle on each side. The margins of all the saddles are entire and the arches of the lobes very finely serrated, and in younger specimens and the inner whorls of others, often entire. Some fragments of young individuals resemble in general shape this species, but show slight deviations in the lobe-line (fig. 7).

Both in general shape and number, and arrangement (though not shape) of the lobe-lines, this species closely resembles the *Lytoceras* genera (*Monophyllites* and *Phylloceras*) of the Muschelkalk and Hallstadt respectively, and may be said to be an earlier stage of these forms.

The earliest appearance of a form belonging to the chain of which the above species is only a link may be said to be *Goniatites bohemicus*, Barr., from the Silurian, and can be traced through a variety of allied species to the Devonian of Nassau, where we find in *Goniatites æquabilis*, Beyr., an exact likeness of our Himalayan species. Both section of shell¹, general characters and striation, agree perfectly, and there is a strong resemblance even in the lobe-line. The external saddle is rudimentary, as is also the second lateral saddle, which is moved nearer the umbilical margin. But there, as in our species, we find a strongly developed and large first lateral lobe, with a bend towards the inner side, closely resembling the later Himalayan species. We have here connecting links of a long chain of forms beginning already in Silurian times and reaching probably high up in the cretaceous series, thus:

Silurian: *Goniatites bohemicus*, Barr., etc. etc.

↓

Devonian: *Goniatites æquabilis*, Beyr.

Lower Trias: *Ophiceras*, etc. etc.

↓

Muschelkalk: *Monophyllites*.

Hallstadt: *Phylloceras*.

etc. etc.

¹ Sandberger's Rhein. Verst., Taf. VII, fig. 10.

OPHICERAS HIMALAYANUM, nov. sp. Plate III, fig. 8.

Shell rather less evolute than in the last described species, the last whorls rapidly increasing in height, and in that resembling more the *Lytoceras simonyi*, Mojs., even than the last species. But both the sculpture of the shell and the lobes differ considerably from *Ophiceras tibeticum*. There are a number of nearly straight, only slightly S-shaped, ribs running across the sides of the shell, which near the commencement of the body-chamber (indicated by a small arrow in fig. 8) almost disappear and change into irregular fine wrinkles and bumps near the umbilical side. What remains of the body-chamber is about one-half of the entire whorl. The siphonal side is rounded, the umbilical margin sharply defined, descending straight down towards the shallow and wide umbilicus. The lobes are identical with those of the following species (figured in fig. 9b).

OPHICERAS MEDIUM, nov. sp. Plate III, fig. 9.

General proportions of the shell the same as those of the last described species, but the shell is nearly smooth and only shows slight radiating wrinkles, which disappear entirely towards the siphonal side and are only slightly bent forward in that region. The lobe-line, fig. 9b, resembles more that (fig. 7) which I considered as a younger individual of *tibeticum*, n. s. The siphonal lobe ends in two sharp points on each side of the divided siphonal saddle; the external saddle is a simple arch, rather wider than high, followed by a narrower, very finely serrated (at the base) first lateral lobe. The first lateral saddle is wider than high and bent towards the umbilical side. The second lateral lobe does not reach so far down as the first, is narrower, but also very finely serrated at the base. The second lateral saddle is low and broad, and reaches over the umbilical margin; on the antisiphonal side I noticed a deep and bipartite antisiphonal lobe with a rounded saddle on each side connected with the second lateral saddle by a finely serrated lobe-line, representing one or more auxiliary lobes.

MONOPHYLLITES WETSONI, Opp., Pal. Mitth. Plate LXXXVI, fig. 2.

Agrees well with Oppel's figure, both in outward appearance and course of lobe-line. It was found only in fragments, but is very common in the upper beds of the lowest Trias group—the Campiler beds of the Alps.

TRACHYCERAS (?) GIBBOSUM, nov. sp. Plate III, fig. 10.

With the above forms occurs an Ammonite, which in outline resembles somewhat *Trachyceras* (Ammon.) *semipartitum*, Von Buch¹, but the latter is involute in a higher degree than my species, and consequently develops several auxiliary lobes which are wanting in our species. I have at present referred this form to *Trachyceras*, but it is very probable that it represents a connecting link between *Ophiceras*, n. g., and *Xenodiscus*, Waag., as exemplified in *X. gangeticus*, DeKon., and *Buchianus*, DeKon., which I venture to include in Waagen's new genus.

¹ Über Ceratites Akad. Wiss., Berlin, 1849, Pl. III.

T. gibbosum is moderately involute, leaving a wide and shallow umbilicus; the shell is thickest, near the middle of the sides, in the region of the "bumps," which occupy exactly the centre-line of the sides, and are about six in number in the last whorl. The inner whorls are quite smooth, and on the surface of the shell itself neither ribs nor striæ are visible. The section of the mouth is oval, widest about halfway up the sides. The siphonal side is perfectly rounded. The body-chamber, as far as it is preserved, amounts to about half a whorl (the arrow indicates the commencement of it, fig. 10).

The lobes are very simple and resemble those of *Ophiceras medium*, n. sp., and partly also those of *Trach. semipartitum*, v. Buch. Besides the low siphonal lobe there are one external and two lateral lobes with one auxiliary lobe, which is situated near the umbilical margin. The antisiphonal lobe is deep and ends in two minute points (fig. 10b).

Tribe: **AEGOCERATIDÆ**, Waag.

Genus: **XENODISCUS**, Waag.

XENODISCUS DEMISSUS, Opp.

1862. *Ammonites demissus*, Opp.: Pal. Mitth., Taf. 86, fig. 1.

1872. *Ceratites carbonarius*, Waag.: Mem. Geol. Surv., India, Vol. IX, Pl. I, figs. 2 & 3.

1879. *Xenodiscus carbonarius*, Waag.: Palæont. Ind., Ser. XIII, Pl. II, figs. 2 to 5.

With the species above described and in the same bed (2) with *Posidonomya angusta*, Hau., and other Werfen bed fossils, occur numerous specimens belonging to a chain of forms which might be roughly described as beginning with the flat and characteristic *Xenodiscus demissus*, Opp., and ending with *Xenodiscus* (?) *buchianus*, DeKon.

I have nothing to add to the description of the above-named species after the excellent exposition given by Waagen in the Palæontologia Indica, but may add, that there can be no doubt that Oppel's figure agrees with Waagen's species, as it does with my specimens. The species is so common in bed 2, that necessarily there is a great variety of forms, all, however, agreeing in the principal characters. They show greatest variation in the ribs or wrinkles of the shell, to which I may add that the shell itself is rather thick, especially so half-way up the flattened sides, and is covered by wrinkly lines of growth, which at intervals develop into ribs.

It is possible to arrange from amongst them a complete chain, passing from the evolute specimens (representing Oppel and Waagen's species) up to considerably involute varieties, and in that stage closely resembling the two species of DeKoninck's *Goniatites gangeticus* and *Cer. buchianus*.

Though Dr. Waagen does not say so in his description of the new genus, I presume that *Xenodiscus* is really the early stage of development of *Aegoceras*, Waag., and stands in the same relation to the latter genus as does *Otoceras* and *Ophiceras*, respectively, to *Pinacoceras* and *Lytoceras*.

GEOLOGICAL SURVEY OF INDIA

Griesbach, Lower Trias Cephalopoda

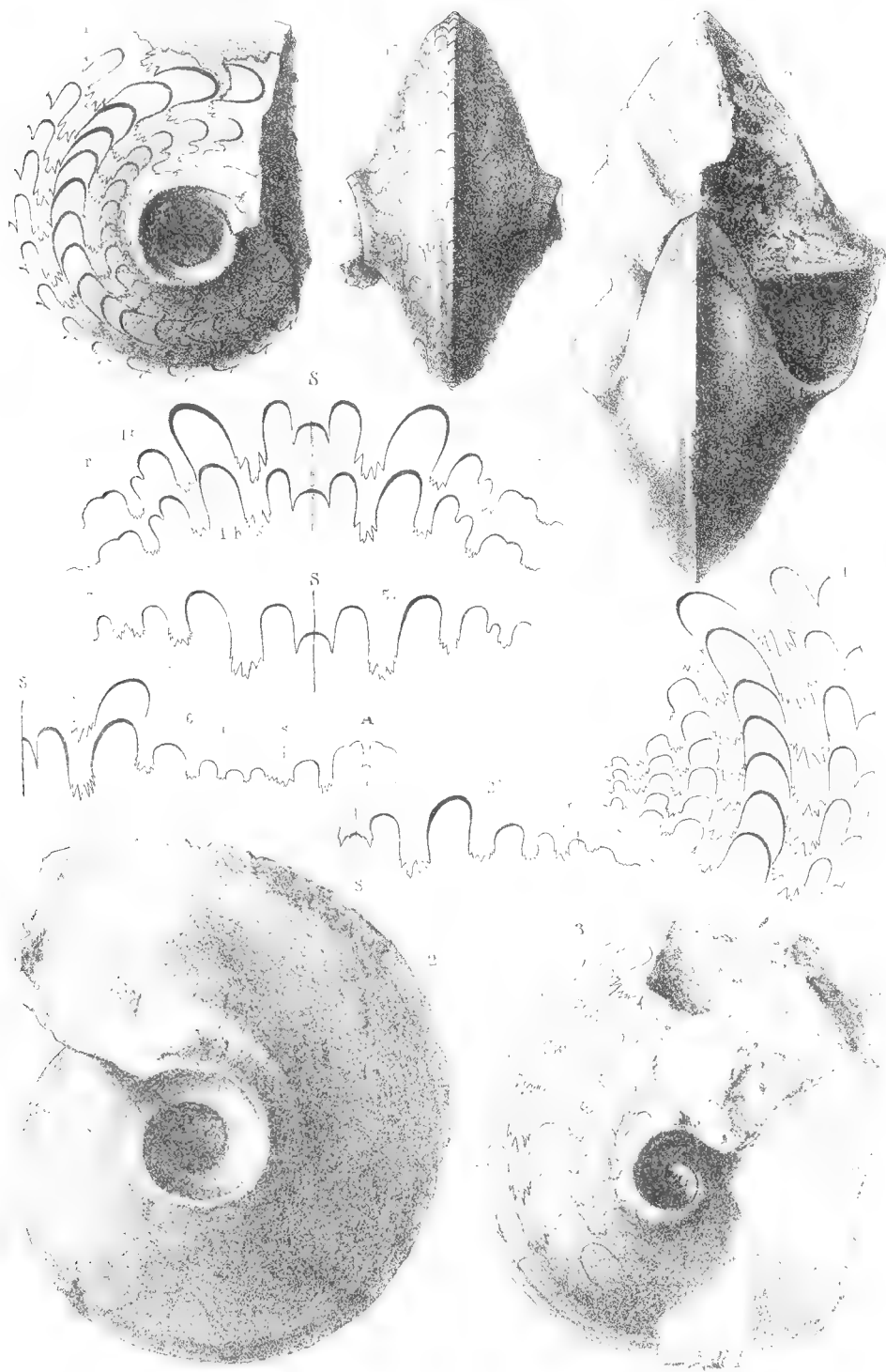
Figures 1-10



GEOLOGICAL SURVEY OF INDIA

Griesbach, Lower Trias Cephalopoda.

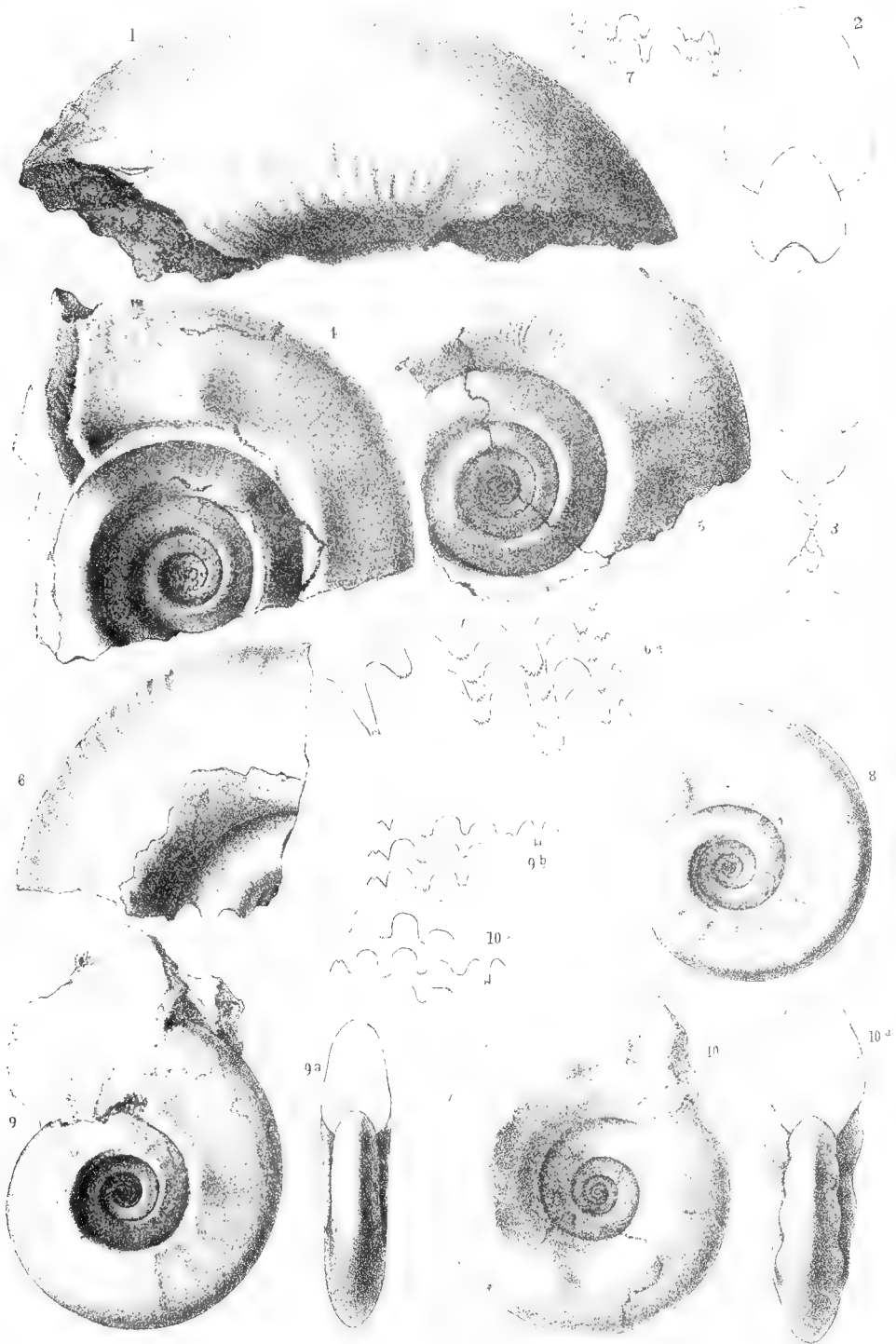
Records Vol XIII. Pl II



GEOLOGICAL SURVEY OF INDIA

Griesbach. Lower Trias Cephalopoda.

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Drawn from nature with the Camera by the author.

PROFILE OF TRIASSIC AND RHAETIC CLIFF OF SCHAL-SCHAL.

Printed at the Geol. Survey Office

EXPLANATION OF PLATES.

PLATE I.

- Figs. 1 to 3. NAUTILUS BRAHMANICUS, n. s.
 Fig. 4. OTOCERAS WOODWARDI, n. s.
 Fig. 5. „ var. UNDATUM, n. s.

PLATE II.

- Figs. 1 to 6. OTOCERAS WOODWARDI, n. s.

PLATE III.

- Figs. 1 to 7. OPHICERAS TIBETICUM, n. s.
 Fig. 8. „ HIMALAYANUM, n. s.
 Fig. 9. „ MEDIUM, n. s.
 Fig. 10. TRACHYCERAS GIBBOSUM, n. s.

PLATE IV.

Profile of Trias and Rhætic beds of Shal-Shal in the Tibetan Himalayas. The elevation of the base of the cliff (carboniferous quartzite) is about 14,000 feet above the sea.

ON THE ARTESIAN WELLS AT PONDICHERRY, AND THE POSSIBILITY OF FINDING SUCH SOURCES OF WATER-SUPPLY AT MADRAS, by WILLIAM KING, B.A., *Deputy Superintendent, Geological Survey of India.*

Some three years ago it was announced that operations had been commenced at Pondicherry with a view to the discovery of artesian wells,—a doubtful enough experiment when the position of that city on a wide alluvial flat bordering the sea is taken into account, and that few of the ordinary physical or stratigraphical features, usually considered as giving promise of such outflows of water, are apparent at first sight. Such features do, however, occur partially; and their possible existence became gradually so impressed on the mind of Mr. Ch. Poulain, the manager of the Savana and Oopallem cotton mills, that he urged on the proprietors the advisability of making experiments, and ultimately carried out a boring with such success that water is now issuing from the tube with a hydrostatic level of nearly three feet over the surface soil and a discharge of 44 imperial gallons in the minute.

Mr. Poulain, from time to time, during the progress of this first well, read a series of papers before the Government Commission on artesian wells, in which he gave his reasons on geological and physico-geographical grounds for expecting that water-bearing strata, or sheets of water with a head, might be tapped under the Pondicherry plain, at the same time giving short notes of the progress of his work.¹ The data so recorded and other information obtained personally from this gentleman have been largely included in the present paper.

¹ See Appendix 2.

I am also much indebted to Mr. Carriol, Chief Engineer of Pondicherry, for his guidance, and for placing of all available information and assistance at my disposal in this enquiry.

The original well at the Savana filature was commenced on the 1st February 1877, and the boring (after several accidents and a removal to a short distance) having been put down to a depth of about 174 feet, the present rising sheet of water began to flow and obtained a height of nearly a foot over the soil and a discharge of nearly 20 gallons per minute on the 10th September in the same year. The flow increased to more than double this amount, and it has now been going on steadily for more than two years.

In the succeeding year a second boring was started at the Oopallem mills, and in the remarkably short period of thirty-seven days, and at the moderate expenditure of Rs. 1,500 (not accounting for apparatus and repairs), a water-bearing stratum was tapped at about 115 feet which is now discharging 99.5 gallons a minute at a height of nearly one foot over the surface, and has continued so since the 11th October 1878.

The French Government being now convinced of the occurrence of water-sheets with a 'head,' determined on developing this unforeseen source of water-supply. A site was selected in the Jardin d'Acclimatation; and under the administration of Mr. Carriol, the Chief Engineer, a third boring was carried out with great success, a sheet of water being struck at 261 feet which has had a discharge of 146.52 gallons a minute, at 4.85 feet over the level of the soil, since the 20th March 1879. This boring was carried out with great care, details and specimens of the strata passed through having been preserved.

It is difficult to give an idea of the very charming and inspiring effect of this fountain so opened up in these gardens, though for a so-called fountain the height of the jet is very insignificant. The large basin is raised well over the level of the gardens for the necessary distribution of the water, while a large rose is placed over the orifice of the tube, so that the water only wells up rather violently and falls in a bubbling mass about a foot over the surface of the sheet in the basin. The mere gush of clear and brilliant water in a country where one so seldom sees water in such joyous motion, rising as it does from an unknown source, makes this fountain a most fascinating and beautiful feature, and soon tends to lead one into an enthusiastic belief in the existence of similar sources, and the possibility of opening them up, in almost any moderately extensive alluvial flat on the coast or even far inland. The Savana well is ill-placed, among the mill buildings in the deep shadow of its service well or basin, and its discharge is not so great; but the Oopallem well makes a brilliant oasis of its grass-grown mound in the otherwise rather sombre factory compound.

The supply of water from this well being sufficient for the gardens, a second boring was started under the same auspices and able administration, on about the most elevated ground in Pondicherry, in the Ville Noire, with the laudable object of distributing water over the native quarter. Here the works are on the same extensive scale, and much larger piping is used. Not, however, until a depth of 550 feet has rising water been met with; and this only comes within 35 inches of the surface, with a discharge of about 20 gallons a minute. This result

is very poor, but it is hopeful, nevertheless, the other wells having also shown similar sheets with such a low hydrostatic level.

A fifth well has also been started by Mr. Cornet, one of the proprietors of the filatures, in his own compound within the city and much nearer to the sea shore. My latest information on this boring is that a stratum of rising water had been struck at 200 feet. The water is not yet very abundant, and it is only of middling quality.

Some trials have also been recently made elsewhere in this part of India, which it is just necessary to notice here. Mr. A. de Closets, C.E., of Madras, reports as follows:—"A trial well I had bored in Madras at the then Napier Iron Works through strata of blue clay and sands alternately, reached at 30 yards an ascending water sheet of brackish water, above a stratum of a greenish kind of sandstone." This well was, I believe, abandoned on financial grounds. Again, in another boring now under operation in Madura, Mr. de Closets has been piercing alluvial strata with the hope of meeting a water sheet, but as yet without success.¹

On the completion of the boring in the Jardin d'Acclimatation, the subject was brought to the notice of the Madras Government through an extract² from the *Moniteur Officiel* of the French Settlements in India, and an enquiry was then instituted as to the expediency of sinking such wells, and as to whether any suitable localities for artesian well-sinking were known in the Presidency. At this time I had only the data supplied in Mr. Carriol's report, and had not seen Pondicherry or its neighbourhood for nearly 22 years, so could only suggest the possibility of such wells being found in similarly placed alluvial flats, while I hazarded the speculation that the gush of the water might be due to the pressure of superincumbent alluvial strata. The interest attached to these wells is, however, so great that a personal inspection of them became necessary, and I was enabled to visit Pondicherry in December last, when the materials for this paper were collected.

THE SAVANA BORING.

Mr. Poulain, though much interested in the strata passed through in this

No very detailed observations extant. working and that at Oopallem, has unfortunately not given very detailed accounts of them in his papers, neither did he preserve an orderly series of specimens of the rocks. Indeed, his paramount interest and object were rather to get at the hoped-for rising sheets of water, one of which should be of a sufficient quantity and of a suitable quality for the mills which had hitherto been supplied with well-water given to depositing a coating in the boilers. The following tabular section (Table I) has, however, been constructed from the papers he read before the Commission; it is arranged after the model of those kept at the Government borings, so as to give the details at a glance, and facilitate any correlation which may be made between the other borings.

¹ In Northern India borings for water have been made to 481 feet (Calcutta), and to 701 feet (Umballa), without success. See *Manual of the Geology of India*, p. 397.

² See Appendix I.

The water here is very limpid with a faint bluish-green tinge; a very slight sulphurous odour is given off. It is reported as good to the taste, savoring an apparent metallic flavour; nitrate of silver gives a faint opaline cloud, and tannin produces no change of color. No deposit is formed on the boilers at the filature. The temperature at the orifice is 33° C. or 91·4° F. Clots and fluffy masses of rusty-green vegetable matter soon gather on the surface of the water in the service well or receiving basin.

The well is situated at about 1,880 yards from the seashore, and about 250 yards from the right bank of the Edoupar, a small tributary of the northern arm of the Ariankip or Gingee river, a short distance outside and to the south-west of Pondicherry. The nearest high ground of older rocks than the alluvial deposits is the low Red Hills plateau which commences to rise from the plain at about 2 miles to the north-west.¹

The tube has an internal diameter of 5·57 inches, and a total length of 172·79 feet, being made up of rivetted segments of 8·20 to 9·14 feet long.

Table I.—The Sarana Boring.

No. of bed according to Mr. Poulet.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Prozressive thickness in meters.	REMARKS.
		Surface soil, say about ...	3·00	3 00	
1	A	Coarse sand, with some rounded pebbles, quartz, and sub-angular particles of (?) basalt.	1·00	4·00	1st February 1877.
2		Coarse sand, such as is employed in the making of lime.	3·40	7·40	
3	B	Black clay with the same sand and pebbles mixed in it.	0·40	7·80	As this clay was pierced, all the water disappeared from the tube.
4		Black clay more compact, scarcely any sand, pearly spangles, fragments of shells.	2·48	10·28	
5		Quartzose sand, stained with black clay, about	0·38	10·66	
6		Pure black clay, very plastic ...	5·34	16·00	
7		Black clay, containing a little sand ...	0·58	16·58	At 16·58, 2nd rise.
8		Pure black clay, and clay mixed with fine and coarse sand.	2·42	19·00	

¹ The height of the surface at the well over mean sea-level is 9 feet. Before the boring the water-level in the ordinary wells was 11·48 feet; but now it has risen to 8·85 feet. This increase has taken place since the surplus water of the artesian well has been allowed to flow into the tank situated in the north part of the premises.

Table I.—The Savana Boring—contd.

No. of bed according to Mr. Pou-lain.	Arbitrary group-ing of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thick-ness in meters.	REMARKS.
9	C	Coarse quartzose sand, brilliant and dull grains, white to yellowish-red, lower down mica spangles.	8.00	27.00	At 22.00, 1st gush.
10	D	Black clay	6.00	33.00	At 33, 2nd gush.
11	E	Grey sand of extreme fineness, fluid and even viscous.	1.00	34.00	Water lowers as boring proceeds.
12	F	Black clay, plastic, compact, with some rare black and schistose pebbles.	2.00	36.00	
13	G	Silicious sand, coarse-grained stained with a little clay.	1.00	37.00	At 36.50, a rise.
14	H	Impermeable bed of clay, less black than the previous ones: containing some grains of calcareous concretions (1 to 5 millimeters cube) and others a little larger. Sometimes a little sand, mixed or in thin seams.	8.00	45.00	
15		Same clay, with rounded pebbles, size of peas, others a little larger, black and white.	1.00	46.00	At 46, 3rd gush, but a fall below soil.
16	I	Coarse sand, with pebbles of quartz ...	0.50	46.50	At 46.50, water stops at 30 centimeters above soil.
17		Coarse sand, pebbles rarer, mixed with fine grey fluid sand like that at 33 meters. Lower in the bed pebbles still more rare, grains of sand very large (2-3 mm. cube) of hyaline quartz, small debris of kaolin.	0.50	47.00	
18		Coarse sand, smaller grains and rolled pebbles.	1.00	48.00	
19		River sand a little mixed with fine sand like sea-sand, still some fragments of white clay; then the sands alternately fine and coarse. (Here were noticed some particles of blackish calcined clay and some fragments resembling country brick, but Mr. Poulain hesitated at such recognition until some small sherds of pottery appeared; even then he admits that these may have fallen from above).	2.00	50.00	At 49.90, water stays at 50 centimeters, when all at once there is a 4th gush. Eventually water lowers rapidly.
20		Coarse sand containing pellets of black clay as large as peas; sand fine and coarse-grained, the two sands being sometimes mixed, soiled with a little black slushy clay.	1.00	51.00	

Table I.—The Savana Boring—concl'd.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
21	J	Debris of friable "psammite" (? ferruginous grit) tainted with some yellow ochreous clay, mixed with sand, rolled pebbles, and some lumps of hard greyish-white limestone.	1.68	52.68	At 52.68, 5th gush, 10th September 1877.
22		Coarse-grained blackish sand, then some debris of ferruginous grit of a deep brown colour, less friable than the preceding, mixed in the mass of coarse-grained white sand slightly soiled with yellow ochreous clay.			

In this table, the strata, their separate thicknesses, the progressive depths, the remarks, &c., are collated from Mr. Poulain's papers already referred to. I have myself taken the liberty of making a tentative grouping of the strata into series of permeable and impermeable beds, or an arenaceous and argillaceous grouping, thus:—

GROUPS OF BEDS.	Feet.	Feet.
Surface soil	9.84	9.84
A.—Coarse sands	14.43	24.27
B.—Black clays	38.04	62.31
C.—Coarse sands	26.24	88.55
D.—Black clays	19.68	108.23
E.—Grey sands	3.28	111.51
F.—Black clays	6.56	118.07
G.—Sands	3.28	121.35
H.—Clays	29.52	150.87
I.—Gravelly and pebbly beds	16.40	167.27
J.—Sands with debris of ferruginous grits	5.51	172.78

The arenaceous beds were always loose and incoherent, never consolidated; the strata passed through are then clearly alluvial and recent. The tertiary red sandstones, or "Cuddalore sandstone" of the Survey nomenclature, cropping up in the low hills to the north-west. have not been touched by the boring rod, much less the cretaceous

strata hading up still further to the west on the shores of the great Oussandan tank west of Pondicherry.

The permeability or otherwise of the beds is very clear in this boring: no sooner is fair clay reached and pierced than the tube (filled with water from the sand above) is gradually emptied, until sand is again reached, when water again appears.¹ A sheet of water, or a seam charged with water, was, however, struck at 54·38 feet, which rose in the tube and ran over at 3·28 feet below the surface of the soil, still above sea level and also above the level in the surrounding wells; so that here was water clearly under pressure of some kind. The seam of sand and clay being, however, very thin, the boring was pushed on through the succeeding clay, until at 62·32 feet a second sheet was found to rise 11 inches over the soil, and after a short time to 17·5 inches. However, as the boring progressed, the water fell again 3·28 feet below level of soil, and then an accident occurred to the tubing which necessitated the starting of a new boring at 2 feet to one side. In the new hole similar strata were passed through, and at 72·16 feet, water at last rose to 15·60 inches above the soil.

The curious feature in the progress of these two borings only 2 feet apart,—that in about 26 feet of coarse sand without any clay the water first rose over the soil, then gradually fell to nearly 3 feet below the surface, and finally rose again to nearly 1·5 feet over the surface,—is attributed by Mr. Poulain to faultiness in his first tube, which he thinks was not quite staunch at the rivetted joinings.²

A third seam of permeable material (E) was again met at 108·23 feet of about 3·5 in thickness, which gave a discharge of water at 35 inches above the soil, but the boring was continued in the hope of obtaining a better flow.

At 118 feet, a 3-foot seam of sandy material only allowed of water rising to within a little more than 2 feet of the surface. It is not clear whether sufficient time was allowed here for the water to rise higher, as it ought to have done, even though retarded through a more compact condition of the sand.

After this came 29 feet of impermeable clays (H), from below which water rose to 3 feet above the soil and then fell to 27·30 inches below that level.

The auger now passed through a more varied set of generally arenaceous beds, without any definite seams of clay or other impermeable material, yet the water rises and falls in a remarkable manner, though ultimately, at the bottom of this series, the point is reached from which the present fine flow of the Savana well rises. There are altogether some 25·35 feet of these sandy beds. After entering on this series, the water mounted slowly and stopped at 11·70 inches over the soil: afterwards it rose as high as 19·5 inches when (as graphically expressed by Mr.

¹ The fact would require that some permeable beds are quite cut off from the artesian (or any other) source, and are still unsaturated, if the word 'emptied' is to be taken literally.

² The explanation would suggest that the phenomenon only occurred in the first boring.

Poulain) all at once, at a stroke of the borer, the water rose rapidly and flowed out over the mouth of the tube at nearly 3·28 feet above the soil. It then fell and rose in the tube, ceased to flow, and finally lowered rapidly, at a depth of 163·57 feet. The auger still continued through what are to all appearance permeable beds, though no further rise took place until at nearly 178 feet, when there was a powerful discharge of sand. This having been gradually reduced, the water rose to a height of 11·70 inches over the soil with a discharge of 19·81 gallons a minute.

I do not think we can here, below the second band of clay, consider that more than one water sheet has been tapped. The odd Does not imply that there are more than one sheet below last seam. behaviour of the water in its oscillations being in great measure attributable to a possible choking up of the material round the bottom of the tube as it was forced down among varied sands, in which are at times seams of clay-galls and other fragments of clayey material: while in the new movements superinduced among the water channels or passages by this suddenly opened-up vent, it is quite possible that there may have been frequent blocks. The height of the jet was, however, poor as compared with what had been attained in the earlier stages of the boring, and this and the discharge were only attained after some days. The discharge when I saw the well in December last was about 44 gallons a minute, with a hydrostatic level of about one foot over soil.

For the beds exhibited by this boring: it is to be noted that there are two Two well-defined seams or bands of clay. well-defined and thick seams of clay which act perfectly as impermeable bands, from under which water rises over the level of the soil. The lower clay seam is, however, separable into three divisions by two thin seams of sand, from each of which there was a gush of water.

THE OOPALLEM WELL.

This is situated within the compound or yard of the Oopallem filature on the Pondicherry-Cuddalore high road, and in the depression of the same small stream passing to the south-west of Pondicherry. It is within Position. 820 yards of the sea shore, but about 650 yards to the south of the parallel of the Savana well, and about 100 yards from the left bank of the Edoupar stream.

The present discharge is 99·5 gallons a minute at a hydrostatic level of The tubing and discharge of water. 3·28 feet. The tube has an internal diameter of 7·08 inches, and is 119 feet long.

The water is very similar in character to that of the Savana well; if anything it appeared to me to be more sparkling and to have The water. rather a bluer tinge. The sulphurous odour is stronger.

The same vegetable matter forms and floats off on the surface, perhaps rather more quickly and in better growth owing to the free exposure to air and light; the bed of the channel leading away from the basin is coated with a somewhat similar growth, and this again is covered by a very thin brown ferruginous scum. The water was distinctly tepid to the touch in the cool weather of December, and is of about the same temperature as that of the Savana; it is drunk freely by the natives.

It is to be noted that the discharge is much over that of the Savana jet. But this appears to be in proportion with the capacities of the tubes, qualified by the different depths and the more compressed strata in the deeper boring. The discharge powers of the two tubes are as 44 to 31: the actual discharges being as 99·5 to 44.

The following table of the strata passed through in this boring has been sent to me by Mr. Poulain :—

Table 2.—The Oopallem Boring.

No. of bed according to Mr. Poulain.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
1	...	Vegetable mould	0·60	0·60	
2	A	Fine sand with clay	2·35	2·95	
3		Coarse sand with pebbles, and some clay near the bottom.	15·18	18·13	Rising sheet to 1 meter below surface.
4		Pebbles with sand, and some clay	0·60	18·73	
5	B	Dark clay with fine sand	2·50	21·23	
6	C	Dark and hard clay	14·47	35·70	Gushing water sheet.
7	D	Fine sand and pebbles ... ..	...	...

The water-level in the ordinary wells is between 6·56 and 9·67 feet below surface soil, which is 6 feet above mean sea-level.

An arbitrary grouping of the beds may be put as follows :—

GROUPS OF BEDS.	Feet.	Feet.
Surface soil	1 96	1·96
A.—Sands and pebbly beds with clay	59·46	61·42
B.—Dark clay with fine sand	8·20	69·62
C.—Dark and hard clays	47·46	117·08

THE BORING AT THE JARDIN d' ACCLIMATATION.

The next well in order of date is that in the Jardin d' Acclimatation, situated between Savana and Oopallem, immediately on the south-west edge of the town, at about 1,450 yards from the seashore, 160 yards south of the parallel of the Savana well, and 170 yards from the left bank of the Edoupar.

The boring was commenced on the 30th October 1878, and the present water-bearing stratum was reached on the 13th February 1879, since which time, with the exception of a few days of gradual rise, the flow has continued at the same height and rate of discharge.

The water and its charge. The water has a temperature of 34.30 C. or 93.74 F.; it is very clear, with a faint bluish-green tinge, and has a slight chalybeate taste. A strong sulphurous odour is given off; and the usual vegetable scum is formed on the surface and floats away. It is drunk freely by the natives, and it boils vegetables perfectly.

The following tabular section (3) is compiled from one supplied to me by Mr. Carriol and from another table given in the Proceedings of the Madras Government, Revenue Department.¹ In this table also, I have attempted a grouping of the beds according to their sandy and clayey constitution:—

Table 3.—The Boring in the Jardin d'Acclimatation.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	BRDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
		Surface soil	1.33	1.33	30th Oct. 1878.
1	A	Sand mixed with yellowish clay ...	0.75	2.08	2.80 M., water-level of surrounding wells.
2		Clay mixed with clear grey sand ...	0.35	2.93	3.60 M., mean sea-level.
3		Argillaceous sand, clear grey ...	1.40	4.33	
4	B	Coarse sand, bluish, containing small pebbles.	0.30	4.63	
5		Sand, clear grey, fine, and very fluid ...	1.37	6.00	
6		Coarse sand, bluish, small pebbles ...	0.15	6.15	
7		Coarse sand, bright grey	0.25	6.40	
8		Coarse sand, bluish, containing small pebbles.	0.30	6.70	
9		Coarse sand, bluish, small pebbles, debris of 'charcoal' and decayed wood.	0.35	7.05	
10		Coarse sand, bluish, galls of black plastic clay, and decayed wood.	0.35	7.10	
11	C	Sand, very fine, bluish	0.15	7.55	
12		Coarse sand, blackish, mixed with black plastic clay.	0.60	8.15	At 10.24 M., first rise of water-level.
13		Black clay and fine sand	2.59	10.74	

¹ 7th July 1879, No. 1496. See Appendix 1.

Table 3.—The Boring in the Jardin d'Acclimation—contd.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in meters.	Progressive thickness in meters.	Remarks
14 }	D	Fine sand and black slushy clay ...	0.88	11.62	
15 }		Coarse sand with a little clay, small pebbles.	0.10	12.02	
16 }	E	Fine sand, decayed wood, no clay ...	1.58	13.60	
17 }		Fine pure sand ...	2.20	15.80	
18 }	F	Black compact clay, with vegetable detritus.	5.40	21.20	
19 }		Black clay mixed with fine and medium sand.	2.90	24.10	
20 }		Black clay mixed with sand and pebbles	0.20	24.30	
21 }		Black clay mixed with medium sand ..	2.80	27.10	
22 }	G	Fine sand soiled with clay ...	0.20	27.30	
23 }		Fine grey sand ...	1.10	28.40	
24 }		Hard black clay mixed with very fine sand.	0.15	28.55	
25 }		Medium sand, greyish ...	2.15	30.70	
26 }	H	Sandy black clay ...	0.15	30.85	
27 }		Fine grey sand ...	0.55	31.40	
28 }		Sandy black clay ...	1.20	32.60	
29 }		Fine sand mixed with black clay ...	0.40	33.00	
30 }	I	Fine sand with clots of sandy clay ...	0.30	33.30	
31 }		Compact black clay mixed with very fine sand and some small granules of grey limestone.	6.70	40.00	
32 }		Plastic black clay with a few fragments of shells.	4.00	44.00	
33 }		Compact black clay mixed with very fine sands.	0.75	44.75	
34 }	J	Black clay mixed with medium sand ...	3.30	48.05	
35 }		Fine sand, dull, earthy and clayey ...	1.35	49.40	
36 }		Fine sand, less dull, earthy and clayey...	5.30	54.70	At 56.50 M., 1st gush.

Table 3.—The Boring in the Jardin d'Acclimatation—contd.

No. of beds according to official table.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS.
37	K	Coarse sand, clayey, containing pebbles, morsels of conglomerate and debris of ferruginous grit.	2.00	56.70	
38		Coarse sand, pure, containing small pebbles, conglomerates and ferruginous grit.	2.50	59.20	
39		Coarse sand, bluish, containing small pebbles, very white clay and ferruginous grit.	0.90	60.10	
40	L	White sandy clay	0.15	60.25	
41		White sand, with small pebbles, fragments of white clay and ferruginous grit.	5.79	66.04	
42	M	Greyish sand, small pebbles, friable white grit and quartzose agglomerate with iron pyrites.	0.56	66.60	At 68.85 M., 2nd gush.
43		Blackish sand, friable white grits, and the pyritous quartzose agglomerate	0.80	67.40	
44		Grey sand, and the same ferruginous rock.	0.50	67.90	
45		Greyish sand, small pebbles, the pyritous agglomerate and decayed wood.	0.70	68.60	
46		Grey sand, gravel, pyritous agglomerate, ferruginous grit.	0.50	69.10	
47		Grey sand, gravel, small pebbles, decayed wood, fragments of white and grey clay, and the pyritous agglomerate.	2.40	71.50	
48	N	Grey sand, very fine and pure ...	0.90	72.40	At 73.60 M., 3rd gush.
49		Fine black-grey sand, fragments of decayed wood and vegetable detritus.	1.20	73.60	
50	O	Medium sand, gravel, small pebbles, decayed wood, and pyrites.	4.20	77.80	At 79.34 M., 4th gush, 13th Feb. 1879.
51		Medium greyish sand, clots of clay, gravel, small pebbles, decayed wood, and pyrites.	0.60	78.40	
52		Medium grey sand, gravel, decayed wood, small pebbles, and pyrites.	1.12	79.52	

Clayey and sandy
grouping of the beds.

My tentative grouping of the beds gives the following
succession:—

	Feet	Feet.
Superficial soil	4.33	4.33
A.—Clayey sands	9.84	14.17
B.—Alternating coarse sands	12.52	26.79
C.—Black clay and fine sand	8.82	35.61
D.—Clayey sands	4.19	39.80
E.—Sands without any clay	12.39	52.19
F.—Black clays, sometimes sandy	37.06	89.25
G.—Alternating sands and clays	11.80	101.05
H.—Alternating sandy clays and sands	8.52	109.57
I.—Thick beds of black clay	48.38	157.95
J.—Fine earthy and clayey sands	21.81	179.76
K.—Beds of coarse sand with some ferruginous matter	17.71	197.47
L.—White sands, clayey and conglomeratic	19.48	216.95
M.—Sands with seams of ferruginous grit	17.90	234.85
N.—Fine sands	6.88	241.73
O.—Sands, gravelly and ferruginous	19.41	261.14

On comparing this succession with that of the Savana well, there does not appear to be very much in common at first sight, except that if we take the same depth in each, there is then the same number of groups. This, however, goes for nothing; but on looking at the groups of beds there does appear to be some faint connexion. In the Savana section, there are four distinct seams of clay, *viz.*, B, D, F, and H, while in this section there are only F and I. B, in the first, is of about the same thickness as the upper clay in the Garden section, which is, however, at a depth of 52.19 feet. A very slight dip to the eastward, which is not an unlikely supposition, would allow of these being the same bed. The clay seam, I, in the Garden well is 48.38 feet in thickness; but its upper surface is very nearly at the same depth below F as D in the Savana well is below B. There the correlation would seem to cease, for we can hardly suppose the 19.68 feet seam (D) of the Savana to have thickened out so tremendously. No other decided clay seams are found in the Garden boring, as if F and H in the Savana might also have

Compared with the
Savana grouping.

run to the deep. It seems more likely that D, F, and H in the Savana may have run into I in the Gardens.

Five rising sheets of water were tapped in the Garden well. The first rise took place in C, but at a point (*vide* Table 3) which seems to indicate that the black clay and the fine sand are separate layers.

Behaviour of the water sheets. During the whole time the boring was going on through the groups D, E, F, G, H and I, there appears to have been a steady rise of water until the 1st gush was reached, even with the intervening (ordinarily impermeable) 37 feet of black clays of F, and the 48½ feet of thick black clays of I. It is very difficult to account for this apparent permeability of such beds, even though the boring was carried on at an average rate of more than 3 feet a day. It may have been that the partings between the separate beds of clay in each group allowed of water percolating from thinned out beds of sand: indeed if my correlation of the lower group of clay beds with the separated clay beds in the Savana section be right, then the intermediate sand beds of the latter section would thin out between the thickening clays of the F group in this boring. This closing up of the water sheets also accounts for there being no such rises of water level as those which were experienced in the Savana boring until the group H was passed.

The 1st gush of water (in the Garden) took place in the group K at 185·32 feet, apparently from the freer coarse sands in the seam. The 1st gush takes place below the second seam of clays. On the boring being continued the water fell at last below the ground level, in the white sands of L, and so it remained until the sands of the middle of M were reached, when there was a 2nd gush, which, however, fell to 12 inches below surface in the same beds. A 3rd gush took place in the fine sands of N, but this water soon fell to level of ground. At last in the ferruginous beds of O, the 4th and permanent gush was reached.

Here there is little apparent correspondence between the behaviour of the springs and those of the Savana well: and certainly the intermittent action of the present water-layers is extraordinary, especially in the occurrence of the 4th gush, which, it is to be remarked, is from bed No. 52 of the Table (3), which bed does not appear to differ from 50 or 51 except in the absence of small clots of clay. It may be that these clots of clay are so matted together as to have formed a temporary impermeable layer. They are present in the bottom layers of N, from under which the 3rd gush arose, while the 1st gush came from slightly clayey beds. It seems to me that it can hardly be said that these gushes, *viz.*, the 1st 2nd, 3rd, and 4th, are really from different water sheets; but rather that they, like the lower ones in the Savana well, are from an irregularly permeated thickness of sands and some clays which required time for free circulation to be brought about. Thus, I would suggest that both the Savana and the Garden well do after all gather their waters from the same group of sandstones.

THE BORING IN THE VILLE NOIRE.

A fourth boring, in the Ville Noire, is still in operation, but as yet there is no definite information as to a satisfactory sheet of rising water having been tapped.

The locality has been chosen on comparatively high ground; but, from the section, I fear it is altogether too near the Red Hills to give much hope of a sufficient supply of water being found in the proper alluvial deposits, though the news of a rising sheet of water is hopeful. The boring is about 800 or 900 yards from the sea, and nearly 1,250 yards north of the parallel of the Savana well; it is also about 350 yards south of a large back-water immediately north of the city.

The inner diameter of the tube is 8·4 inches, but now that a depth of 550 feet has been reached, it is proposed to insert a second tube of 6·4 inches in diameter.

The following sectional table (4) is translated from a copy of the books kept at the boring, and I have in it again—though there is here no such very decided grouping of the arenaceous and clayey strata as in the southern wells—attempted a classification of the beds:—

Table 4.—The Ville Noire Boring.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
		NATURAL EARTH.	0·50	0·50	
1	...	Fine pure sand, yellowish ...	...	1·00	1·50
2	A	Medium sand, clean, reddish	...	0·10	1·90
3		Fine clean sand, grey ...	...	3·50	5·40
4		Fine grey earthy sand ...	...	1·70	7·10
5		Fine bluish earthy sand ...	...	3·60	10·70
6	B	Blackish sand, dirty, slimy, massive shells and crustacea, small pebbles, grey grit very hard.	3·34	14·04	Represented in bed 4 of Savana boring and perhaps by 9 and 10 in the Garden well.
7		Black clay, ? in laminae, mixed with sand, shells, crustacea, small gravel, and decayed wood.	2·27	16·31	
8		Black plastic clay, containing decayed wood.	4·49	20·80	
9		Compact black clay, mixed with very fine micaceous sand, and some small calcareous granules.	4·29	25·09	

Table 4.—The Ville Noire Boring—continued.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	Beds.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
10	B	Greyish clay, mixed with very fine sand	1.60	26.69	
11		Medium sand, soiled with black clay ...	1.25	27.94	
12	C	Medium sand, fine and clear grey ...	0.47	28.41	
13		Coarse dirty-grey sand, containing small pebbles.	4.01	32.42	
14	D	Black plastic clay ...	4.15	36.57	
15		Fine black clayey sand ...	0.40	36.97	
16		Clay marbled with reddish and bluish tints, coarse sand and pebbles.	6.92	43.89	
17		Pale yellow medium sand, soiled with clay.	2.00	45.89	
18	E	Dirty-grey coarse sand mixed with pebbles.	0.80	46.69	
19		Coarse sand soiled with clear yellowish clay, mixed with small pebbles of grit and ferruginous conglomerates.	1.60	48.29	
20		Coarse sand soiled with reddish clay, ferruginous pebbly grit and small pebbles.	0.80	49.09	
21		Blueish white plastic clay, mixed with red sand and some pebbles.	1.20	50.29	
22	F	Pale-yellow sand, gravel and pebbles ...	0.40	50.69	
23		Sand soiled with reddish clay and mixed with pebbles.	0.45	51.14	
24		Reddish yellow sand, small white and red clay-galls, grit and pebbles.	9.14	60.28	
25		Yellow-brown medium sand ...	1.60	61.88	
26	F	Laminae of colored clay and pebbles ...	0.86	62.74	
27		Grey black clay with some gravel ...	0.29	63.03	
28		Plastic clay, ribboned black, yellow, red and grey.	0.30	63.33	
29		Plastic black clay and a little sand ...	0.20	63.53	
30		Coarse purple argillaceous sand, with patches of colored clay.	1.00	64.53	

Table 4.—The Fille Noire Boring—continued.

No. of bed according to official diary	Arbitrary grouping of Mr. King.	Desc.	Thickness of beds in meters.	Progressive thickness in meters.	REMARKS
31		Agglomeration of vegetable detritus, compact lignite and some grains of fossil resin.	0.91	65.44	
32		Reddish clayey sand, patches of red clay, ferruginous grit and iron pyrites.	1.65	67.09	These pyrites beds seem to be represented at about the same depths in the Garden well, down to 70.52 meters.
33		Bluish-red sand, ferruginous grit, pyrites and pebbly.	1.05	68.14	
34		Medium sand soiled with reddish clay ...	0.34	68.48	
35		Clear red sand and small pebbles	1.61	70.09	
36		Red earthy medium sand, small pebbles	2.40	72.49	
37		Clear yellow argillaceous sand, gravel and milky-white pebbles.	1.35	73.84	
38		Clear red sand, gravel and ferruginous grit.	2.43	76.27	
39		Grey black argillaceous sand, small pebbles and iron pyrites.	0.29	76.56	
40		Clear red sand, small pebbles, and patches of clay at the bottom.	5.64	82.20	
41		Coarse grey sand, with small pebbles ...	0.45	82.65	
42		Pure canary-colored sand, small white pebbles and ferruginous grit.	1.89	84.54	
43		Golden yellow argillaceous sand and small white pebbles.	2.51	87.05	
44		Yellowish argillaceous sand, colored sandy clay-galls and ferruginous grit.	1.60	88.65	
45		Dirty reddish coarse sand, pebbles, ferruginous grit, and patches of colored clay.	0.40	89.05	
46		Yellow-red sand and colored sandy clay	2.26	91.31	
47		Fine yellow-red argillaceous sand with patches or laminae of colored clay.	2.37	93.68	
48		Dirty yellow medium argillaceous sand, ferruginous grit and gravel.	2.06	95.74	
49		Dirty grey sand, clots of bluish sandy clay with vegetable matter.	0.11	95.85	
50		Ashy blue plastic clay ...	0.15	96.00	

Table 4.—The Ville Noire Boring—continued.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
51	G	Grey sand with clots of colored clay ...	0.22	97.06	
52		Fine variegated argillaceous sand ...	0.73	97.79	
53		Yellow sand with clots of variegated clay, small pebbles.	0.33	98.12	
54		Clear-red sand soiled with clay ...	1.75	99.87	
55	H	Yellowish sand and sandy clay, small pebbles.	1.19	101.06	
56		Coarse yellow sand, soiled with clay ...	2.53	103.59	
57		Ashy grey sand ...	0.81	104.40	
58		Ashy blue sandy clay ...	0.49	104.89	
59	I	Variegated sandy clay ...	0.50	105.39	
60		Grey sandy clay ...	3.06	108.45	
61		Fine yellowish argillaceous sand, gravel and ferruginous patches.	6.64	115.09	
62		Clear purple argillaceous sand ...	1.00	116.09	
63	J	Yellow sand soiled with clay, small pebbles and ferruginous grit.	6.89	122.98	
64		Reddish sand soiled with clay, small pebbles	0.43	123.41	
65		Yellowish sand soiled with clay ...	1.78	125.19	
66		Reddish-grey sand soiled with clay ...	1.57	126.76	
67	J	Yellow sand soiled with clay, slabs ('plaquettes') of ferruginous grit.	5.45	132.21	
68		Fine sand, clots of black clay mixed with vegetable detritus.	0.92	133.13	
69		Yellow sand, with slabs or patches of colored clay.	2.98	136.11	
70		Fine bluish-white sand with slabs of iron pyrites.	1.17	137.28	
71	J	Medium grey sand ...	1.80	139.08	
72		Medium grey-black sand with slabs* of iron pyrites.	2.08	141.16	* These slabs are composed of white quartz grains and iron pyrites; tolerably hard and compact.
73		Agglomerate of vegetable detritus mixed with very fine black sand.	0.25	141.41	

Table 4.—The Ville Noire Boring—concluded.

No. of bed according to official diary.	Arbitrary grouping of Mr. King.	BEDS.	Thickness of beds in metres.	Progressive thickness in metres.	REMARKS.
74	J	Coarse black argillaceous sand with iron pyrites.	0 99	142·40	Water is rising from this depth, and flowing out at 2·96 feet below the surface level, with a discharge of 13·21 gallons a minute.
75		Ashy blue clay and vegetable matter ...	3·13	145·53	
76		Foliated ashy blue clay ...	0·10	145·63	
77		Medium grey-black sand ...	1·37	147·00	
78		Ashy blue clay, vegetable detritus, and very fine sand.	0·10	147·10	
79		Black sand soiled with clay, small gravel and vegetable matter.	1·00	148·10	
80	...	Dirty black-grey sand, small pebbles ...	1·96	150·06	
81	...	Yellow sand, ferruginous grit and conglomerates.	0·90	150·96	
		Grey sand soiled with clay, small pebbles.	0·60	151·56	
				164·50	

Tentative grouping.

	Feet.	Feet.
Natural earth	1·64	1·64
A.—Sands	44·41	46·05
B.—Thick beds of clay	45·59	91·64
C.—Sands, with seams of pebbles	14·69	106·33
D.—Clays and clayey sands	44·18	150·51
E.—Varied beds of sand, pebbly, conglomeratic, and clayey	52·44	202·95
F.—Clays and clayey sands	8·69	211·64
G.—Mixed beds of sand, clays, and gravels	130·77	342·41
H.—Sandy clays	13·28	355·69
I.—Sands, somewhat clayey and ferruginous	90·72	446·41
J.—Mixed sands, clays, and sandy or argillaceous beds, with some pyritous sands, and seams of vegetable remains	39·32	485·73
K.—Sands with pebbles and conglomerates	11·34	497·07

All these beds are still essentially loose and incoherent, with the exception of the occasional bands or slabs ("plaquettes") of ferruginous grit; and so belong to the proper alluvial deposits. It is true that they are becoming ferruginous and of yellow and red colors, and are thus somewhat like beds of the Tertiary "Cuddalore sandstones" of the Red Hills plateau to the north-westward, but they are merely the debris of these sandstones, the same kind of accumulations occurring along the edge of the rise up to the Red Hills as near the village of Mootnapallem. It may then be that the auger is nearing the Tertiary beds, but I do not think it is yet in them: certainly it was not in them when I was at Pondicherry, and then the sludge pump was bringing up stuff from 500 feet deep.

In comparing this section with those of Savana and the gardens, it would seem as though we still had the two broad series of clays, though they are hardly so sharply defined and compact. The presence of shelly and crustacean remains in the Savana and this section is perhaps the safest ground to go on for a comparison, and these are in the upper parts of the uppermost clay bands. Such remains were not noted in the garden boring, but it may be that the clay with vegetable detritus at 69 feet answers to it. However, if these clay bands are the same, it is difficult to account for no gush or even rise in the Black Town well so far.

If the seams of clayey and sandy layers, down to below the second band of clay, be the same, then some explanation may be given for the non-rise of water in this boring. From the Savana well to the Ville Noire section, there is a very slight dip to the northward of the impermeable bands, along which sufficient friction may be developed to stop a rise. Again, the Ville Noire clay seams dip to the garden well at a quicker angle: so that really, though the supposed head of water would allow of all the seams being evenly filled up with water, it may be that the flow to the dip is stronger than the tendency to rise in the Black Town well.

This would open up the question, whether the discharge at the Savana and in the gardens may not be sufficient to operate against the tendency to rise in the Ville Noire; and again, whether the water-supply of these wells is so great as the implied storage from the two rivers and the wide alluvial basin in the neighbourhood of Pondicherry.

SUMMARY OF DATA AND CONCLUSIONS.

The data thus obtained regarding the flow of water, the water itself, the strata passed through, and the position of the wells, and the conclusions and conjectures which I have been able to draw from them, may now be summarized as follows:—

There has been a continuous discharge from each of the wells for one year at least, and one of them has been flowing for two years and six months. The hydrostatic level gradually increased, within a short time, up to a certain point and has remained so

Compared with the other borings.
The flow and gush of water steady.

without any sensible diminution up to the present time. The discharge also gradually obtained its present rate, and there has been no sensible decrease.

The gush must then be due to hydrostatic pressure, and the wells must be considered, as was always contended for by Mr. Poulain, as properly artesian.

The water is generally of the same quality and constitution in each well; if anything, that of the Oopallem well is brighter, clearer, and of a bluer tinge. It contains the same vegetable germs.

The borings are all in the alluvial deposits; but one of them (that of the Ville Noire) is near the bottom of these. There is a certain relation between the beds pierced in each bore-hole, which leads to the conclusion that groups of them are continuous over the area tapped. The upper clay seam or band certainly appears to be the same in all; it is very nearly the same thickness throughout, and it is the estuarine set of beds usually found at such a depth on the Coromandel. The second clay seam is not so clearly represented in each section; but there are strong points of similarity. A peculiar pyritous set of beds associated with seams of vegetable debris occurs once in the garden well and twice in the boring at the Ville Noire, and that in the former appears to correspond to the upper one in the latter.

The Savana, Garden, and Oopallem wells are nearly in a line ranging, from the first, in an east-south-east line for about 470 yards to the garden, and then south-east-by-south for about 770 yards to Oopallem, that is, tolerably in the line of dip which the strata might be supposed to have in this locality.

In the Savana and Garden wells, the upper clay seam has a dip of 2° to 3° to the eastward, and from this line it rises slightly to the Ville Noire section. Very nearly at the same depth below the upper clay band comes the second seam, but it has a flatter lie; indeed, it would appear to be almost horizontal in the triangular area formed by the Savana, Garden, and Ville Noire points.

A rise of water took place in the Gardens from the sandy beds above the upper clay seam, which seems to indicate that its head may be at no great distance from Pondicherry.

Conjecture as to the "head" of the 1st rise of water; and the Oopallem sheet. Water gushed in this and the Savana borings from the permeable band below the upper clays; but the flow did not give promise of permanency. I think, however, the Oopallem water rises from the arenaceous band between the two main clay seams.

In both the Savana and Garden wells the jet now obtained began at different levels in the arenaceous strata below the second clay seam. It is questionable whether these rise from separate sheets.

If the upper clay seam preserves its dip and is continued to the westward, it might crop up to the surface at two miles back, or in the bed of the Ariancup or Gingee river at only a few miles west of Pondicherry. It is also possible that the lower seam might crop up within six miles west of the new vents. On this it is conjecturable that the

Oopallem well may draw its waters from a source within six miles of Pondicherry.

THE PONDICHERRY-CUDDALORE ALLUVIAL BASIN.

The wells are then all in the alluvial deposits; indeed, as will be seen later on, it was not to be expected that any but very deep borings could reach the older rocks, which by their lie might be presumed to hold water with a head; it therefore becomes necessary to enquire into the condition of these deposits in this region which give this hydrostatic level to their waters at the sea-board.

Mr. Poulain is, I think, firmly convinced that the head of water is gained on the distant western edge of the alluvial plain behind Pondicherry from the Pennár and Gingee rivers, his arguments being fully given in his series of papers¹ read before the Artesian Wells Commission. The facts relied on are the hydrostatic level, much diminished, however, by friction in the distance traversed by the water; the immediate growth in it, after discharge, of vegetable matter similar to that seen in the river mentioned; and an apparent rise of the hydrostatic level in accordance with an observed rise in the rivers. The endurance of the flow is again very suggestive of a constant and large supply of water, such, indeed, as we might think could only be kept up by two rivers of this size and a large basin for its reception and storage.

Remarks on these. The correspondence between the rise of the rivers and any rise in the jets requires more and very careful observation, and Mr. Poulain expressed himself to me as not being very sure on this point. The vegetable matter is certainly similar to that seen floating along the river channels, but the same growth may be observed on the surface of most wells and certainly in the channels leading from them. Little can be made out of the quality of the water, for it must have undergone many changes in its passage through the different beds, even if it percolated only along one series. I should certainly never take it to be water from the higher levels of the Gingee or Pennár, for, outside of the alluvial area these waters have travelled over gneiss which is frequently weathered, and over soda soils. To all appearance, it might have come from the great tank some 7 or 8 miles to the west of Pondicherry.

However, there is the hydrostatic level which requires a head, and some distance is required for that in a gently sloping plain. For the constant and large supply of water, so far, the difficulty is not great, the whole amount discharged from the three wells in the year being only about 160,065,975 gallons, or say 737,000 cubic yards.

The alluvial basin. The Pondicherry-Cuddalore alluvial plain or bay may be said to have its head at the village of Allabadi on the Pennár at about 27 miles west of the sea shore. From this point, the bay widens out to the east-north-east and east-south-east, the one edge going away, without much indentation, towards Cuddalore, which town is situated on the southern seaward arm or horn of the plain, while the other bends round in two loops up

¹ Travaux des Commissions Locales, Pondicherry, 1877.

the Gingee valley before it trends round again with a south-east curve towards Pondicherry. In this way the plain widens out considerably for a time until it has a breadth of some 24 miles, and then it closes in towards the sea-coast to a breadth of some 12 miles between the low plateau headlands of the Red Hills of Pondicherry on the north and Capper Hill near Cuddalore to the south, after which it again widens out to the sea beach by the two arms or horns already mentioned, only the northern horn is flanked to the sea by the Red Hills, which drop down in low cliffs to the belt of sea sands.

The area of the plain may be roughly stated at 500 square miles, and the boundary or edge receptive of waters from the adjacent rising ground may be taken as 150 miles long. The drainage supply of this basin is, however, tremendously increased by the two large rivers flowing into it.

An estimate of the surface inclinations may be made from a calculation by Mr. Carriol, who states that the village of Villapuram (23½ miles due west of Pondicherry) is 154·84 feet above mean sea-level, which would give a rise of 6½ feet in the mile. Allabadi at the head of the plain is about 12 miles further west, and at the same rise would be 232 feet above the sea; but as Villapuram is at the end of a spur of rather elevated ground between the two rivers, there can hardly be such a difference between it and the bed of the Pennár below the above village. It will be safer to take the level of the river bed as about the same as that of Villapuram: so that from its debouchment on the plain to the coast there is a fall of at least 4·36 feet in the mile.

The basin in which the alluvial deposits of the plains are laid down appears to slope gradually from its western edges, but to deepen more suddenly on its north and south edges, though it again has a shelving edge on the seaward side of the Pondicherry Red Hills. The borings themselves do not show very much as to the thickness of the deposits, though that in the Ville Noire makes it 542 feet, comparatively close (about 1½ miles) to the Red Hills. As far, too, as these borings go, there appears to be a tolerably flat lie of the beds, or at any rate a very low dip of between 2° and 3° to the eastward.

The floor of the basin is a wide hollow worn in the gneiss or bottom rock of the country, its northern and southern edges being of the overlying cretaceous and tertiary strata which were once continuous over what is now the hollow. The latter formations are dipping at low angles to the eastward, and form a slightly elevated country to the westward of Pondicherry and Cuddalore; so that a traverse from either of these places passes from the alluvium to the rising plateau hills of red tertiary sandstones and conglomerates (Cuddalore sandstones) of the Red Hills, across these and down to a lowlying belt of cretaceous rocks, and then on to the further rising grounds of the crystalline or floor rocks. At the Pondicherry side, this order of outcrop is not quite so regular; here the red sandstones have not been so completely denuded to the westward, and thus a patch (the well-known fossil wood beds) of these still remains at Trivucari lapping over the cretaceous beds on to the gneiss.

The stratigraphy of the formations older than the alluvium is thus so far favorable for artesian borings, were the latter carried to a sufficient depth; but it is just this depth and the probability of having to pass through the hard and coarse grits and conglomerates of the Cuddalore sandstones which would make them impracticable.

Considerations on other localities suitable for artesian wells.

The wells are then sunk in the northerly seaward corner of an extensive coastal alluvial plain or basin, into which flow two large rivers whose waters may be relied on in great measure for keeping the permeable strata well filled, and which spreads back far enough from the coast for its surface inclination to give a head to these waters. Such is the broad and patent condition of affairs here; hence in enquiring as to the suitability of other parts of the Coromandel (or even further inland) for artesian borings, the most evident requirement is that they should have all the capabilities of the Pondicherry-Cuddalore basin to ensure success.

Nevertheless, there are certain points (some of them already hinted at) Doubts as to the necessity for so large a basin. which make me doubt whether the size of this basin or the large supply of water received into it, or even the head attainable at the entrance of the rivers on the plain, are really necessary for the discharge and hydrostatic level attained. It is a question with me whether, for instance, the same hydrostatic level could not be attained with a much lower head, at a lesser distance from the vents; there being no doubt that the supply of water, obtained so far, is not beyond what the Ariancup river could give to absorbent strata only a few miles from its mouth. The irregular oscillations of the water rise in the southern bore holes; and the failure of a rise in the Ville Noire boring through all the strata which appear to correspond to those of the former wells and for such a depth seem also to point to a head not far distant, and only a moderate supply of water. I find it hard too to believe in the implied great extension of the impervious seams or bands met within the borings; the few outcrops of alluvial strata which I have seen in high river banks having generally given indications of ultimate thinning out within comparatively short distances, for the most part up, but very often down, the river's course. It is again difficult for one to conceive that the borings, so very shallow in such a wide plain, south of the town, have run down anywhere near strata holding water absorbed in the higher reaches of the rivers within the edge of the basin.

The town of Cuddalore, situated as it is at the southern seaward corner of the same basin, is, on the face of it, the most obvious place to try first. But the city of Madras is for many reasons the more important site. At the same time, there would appear to be even better sites than Cuddalore, on the deltas of the Cauvery, Pennér, Kistna, and Godavari.

Madras, though on the edge of a remarkably long belt of coastal alluvium, is directly in front of only a small alluvial bay or plain, very much smaller than that of the French settlement: so that if it were necessary to go entirely on the charac-

Madras at first sight not so favorably situated.

ters of the latter area, there would not be much probability of success here. Its alluvial deposits are, however, not confined to this bay, but are connected, to the north-west, with the great flat of the Cortelliar and Narnaveram river basins, the permeable beds of which may trend down in this direction.

This western plain is flanked to the north and south respectively by the Red Hills and by the St. Thomas' Mount range of high ground, whence it spreads outwards and seawards, joining the Cortelliar alluvium on the one side and stretching down the coast to Covelong on the other. It extends to the westward by a long arm, at the western end of which it is again connected with the Cortelliar alluviums by a narrow neck across the south-westerly extension of the Red Hills plateau; and it sends another good arm to the south-west past the Palaveram hills. Its extreme length to the western neck is about 20 miles, the breadth between the two low headlands being about $7\frac{1}{2}$ miles. The receptive edge is not more than 80 miles in length, and the area, including the stretch to the coast, is at a rough calculation about 175 square miles. It is only fed by the Triplicane (also called the Madras river and the Cooum) and the Saidapet (otherwise the Adyar) rivers, which have, however, only small drainage areas. There is a possibility, however, that a fair supply of water may be drawn in at the western neck by the narrow channel there connecting the Cortelliar alluviums with those of the Triplicane river. In fact, unless there is a supply of this kind at that point, no head of water can, I think, be reckoned on until within 8 miles of Madras, when waters would have a sufficient receptive edge and length of river bed for their collection.

There is every reason to suppose that the uppermost of the two clay bands at Pondicherry may even be found in the Madras plain, the same kind of shelly deposit having been met with in the few shallow borings which have from time to time been made, while the extent of this plain compared with the size of the streams flowing into it seems to indicate a wide-spread or westward extension of estuarine beds.

I have already expressed my opinion that the water of the Oopallem well is from the permeable band under the upper clay seam of the Pondicherry plain, and there is just a possibility that this permeable seam may crop up in the Gingee or Ariancup river a few miles west of the town. This is a bare possibility only, which, however, does not practically affect the Pondicherry supply; but it is the only supposition which gives promise of any rise from small basins like that of Madras, and it may be that the head gainable at 6 or 8 miles from the coast would be sufficient for a rise. The quantity of water is, I believe, attainable in the Madras bay, within 8 miles of the town.

Fortunately, however, as I think, for Madras, it is situated on the southern arm of the Cortelliar and Narnaveram plains, and in these there are, to all appearance, all the necessary requirements as to head of water gained by distance on a gentle rise, combined with a very large reception edge. The Cortelliar plain is also joined in a remarkable way with that of the Palar river at a point above where the latter has a clear channel through the gneiss, and it is not at all improbable

Its proper alluvial bay small, but still possibly able to supply water with a head.

The proximity of the Cortelliar and Narnaveram plains.

that there is at this high level barrier a take-off of the Palar waters into the Cortelliar basin. There is, of course, first the chance that the permeable beds of the Cortelliar may not stretch downward to and under Madras; but this is hardly to be expected, after what is known of the tailing-up of the water-bearing strata of Pondicherry, even though that town be on the north arm of its plain, and that there is a well-known tendency of the rivers on the eastern coast to trend up to the northwards in their alluvial basins.

There are, on the other hand, dangers that borings may meet with obstructions or may not be able to run deep enough at Madras itself, though it is possible these may not be encountered at a short distance west or north of the city: indeed, the chances of reaching the Cortelliar beds would be increased the further north the trials were made. The line of the Palaveram and Mount ridges of gneiss may extend for some distance underneath the alluviums towards the town; in any case the mere rising ground itself has a tendency to shelve under the Adyar, and this floor would very likely come within the range of shallow borings. Again, it appears¹ that a boring was many years ago made at the then Inland Customs House at Madras, three-quarters of a mile from the sea, to the depth of 55 feet, which reached the crystalline rocks. The obstacle may indeed have been a boulder of those rocks, such being sometimes met with in the alluvium, but the likelihood is that it was a sub-alluvial extension of the Mount ridges.

The section² in this boring was as follows:—

	Ft.	Ins.
Sand and clay	3	0
Light-coloured sand and clay	1	0
Stiff clay	3	6
River sand	5	6
Black clay mixed with sand and shales	20	0
Blue clay with sand and lime and pieces of ironstone	12	6
Granite and quartz rubble	0	6
Clay and gravel mixed with broken granite, quartz, mica, &c.	9	0
TOTAL	55	0

¹ See Manual of the Geology of India, pt. I, p. 423.

² Newbold: Journ. Royal As. Soc., pt. VIII, p. 248.

APPENDIX I.

No. 1426, dated 7th July 1879.

Proceedings of the Government of Madras, Revenue Department.

TRANSLATION.

Extract from the "Moniteur Officiel" of the French Settlements in India, dated Friday, the 4th April 1879.

ARTESIAN WELLS.

In publishing the report of the Colonial Engineer, President of the Commission on Artesian Wells, on the boring operations carried on in the Jardin d'Acclimatation, the Administration desires to draw attention to the important results obtained, and to the hopes which this successful experiment should give rise to as regards the interests of agriculture. It is, in effect, advisable that private industry taking advantage of the experience acquired, should apply the same processes to borings to be made in other parts of the territory.

The Administration proposes, moreover, to utilize the apparatus which the Colonial Council first thought of getting out from France, on works for which sanction will be requested from the Elective Assemblies, with the view of extending these boring operations which are more productive and useful in this Colony than anywhere else.

ENCLOSURE No. 1.

Report on the Operations of Boring an Artesian Well in the Jardin d'Acclimatation at Pondicherry, dated Pondicherry, 24th March 1879.

Mons. l'Ordonnateur.—Conformably to your communication, No. 333 of the 15th February last, I have the honor to forward a full report on the operations connected with boring an artesian well in the Jardin d'Acclimatation at Pondicherry.

In order that the report may be complete, I have deemed it necessary to go back to the formation of the Commission appointed by order of the 23rd February 1877, and to the commencement of the operations which decided the Administration to encourage and popularise an advance in the means of the Colony, and of which the results ought to prove most beneficial to agriculture and rural requirements.

Consequent on the success achieved in sinking an artesian well by the aid of the "Savana" Machine as carried out by Mr. Charles Poulain, Manager of Poulain's Spinning Factory, a Commission appointed by an order of His Excellency the Governor, dated 23rd February 1877, under the presidency of the Colonial Engineer and Chef du Service of Roads and Bridges, proposed to the Administration on the 20th of June of the same year that a complete set of machinery for boring should be procured. This Commission intimated their preference for that of Messrs. Dégousée and Lippman to any other, and suggested that a sum of 1,200 francs should be placed at the disposal of Mr. Charles Poulain (who found himself without funds) in order that he might carry on his work.

The machinery arrived in the Colony on the 4th September 1878, and the Commission, after visiting the Jardin d'Acclimatation, were unanimously of opinion that the well ought to be sunk in the centre of the basin in that garden, that situation being the one which offered the greatest facility for irrigating so large an extent of ground presuming the probable success of the undertaking.

After fitting and erecting the crane, the works were carried on under the supervision and with the assistance of the Department of Roads and Bridges. First of all, a small well 1·80 metre deep was dug in the centre of the basin, at the bottom of which boring was begun on the 30th October 1878, commencing with tubes of a diameter of ·26 of a metre. The work which on this date has reached 79m. 52c. in depth has passed through the following series of geological strata:—

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry.

Number of Strata.	Dates.	Geological Strata.	Thickesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
0	30th October 1878	Natural earth	1·33	1·33	(m. 2·80) water-level of surrounding wells. (3·60) mean sea-level.
1	30th " "	Sand mixed with yellowish clay	0·75	2·08	
2	30th " "	Clay mixed with clear gray sand	0·85	2·93	
3	31st October and 2nd Nov. 1878.	Clear gray sandy clay ...	1·40	4·33	
4	4th November 1878	Coarse bluish sand mixed with small gravel.	0·30	4·63	(10·24) first rise of water-level.
5	5th, 6th, 7th, 8th, 9th, and 11th November 1878.	Fine, clear gray sand, very fluid	1·37	6·00	
6	12th November 1878	Bluish gray sand mixed with small gravel.	0·15	6·15	
7	12th and 13th Nov. 1878.	Coarse clear gray sand ...	0·25	6·40	
8	13th November 1878.	Coarse bluish sand mixed with small gravel.	0·30	6·70	
9	13th " "	Coarse bluish sand, small gravel, fragments of charcoal and decayed wood.	0·35	7·05	
10	14th " "	Coarse bluish sand, lumps of plastic black clay and decayed wood.	0·35	7·40	
11	14th " "	Very fine bluish sand ...	0·15	7·55	
12	14th " "	Coarse blackish sand mixed with black clay.	0·60	8·15	
13	15th " "	Black clay and fine sand ...	2·69	10·74	
14	15th " "	Fine sand and diluted black clay	0·88	11·62	
15	15th, 16th Nov. 1878	Coarse sand with a little clay and small gravel.	0·40	12·02	

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—contd.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
16	16th, 18th „ „	Fine sand and decayed wood ...	1·58	13·60	
17	18th, 19th, 20th, and 21st Nov. 1878.	Fine pure sand ...	2·20	15·80	
18	21st, 22nd, 23rd November 1878.	Close black clay with vegetable detritus.	5·40	21·20	
19	23rd, 25th, and 26th November 1878.	Black clay mixed with fine and moderate sized sand.	2·90	24·10	
20	26th November 1878	Black clay mixed with sand and small gravel.	0·20	24·30	
21	26th and 27th Nov. 1878.	Black clay mixed with moderate sized sand.	2·80	27·10	
22	27th November 1878	Fine sand stained with clay ...	0·20	27·30	
23	27th and 28th Nov. 1878.	Fine grayish sand ...	1·10	28·40	
24	28th November 1878	Hard black clay mixed with very fine sand.	0·15	28·55	
25	28th and 29th Nov. 1878.	Moderate sized grayish sand ...	2·15	30·70	
26	29th November 1878	Black sandy clay ...	0·15	30·85	
27	29th „ „	Fine gray sand ...	0·55	31·40	
28	30th „ „	Black sandy clay ...	1·20	32·60	
29	30th „ „	Fine sand mixed with clay ...	0·40	33·00	
30	30th „ „	Fine sand and lumps of sandy clay ...	0·30	33·30	
31	30th November, 1st, 2nd, 3rd, 4th Dec. 1878.	Close black clay mixed with very fine sand and quantities of gray limestone.	6·70	40·00	
32	5th, 6th, 7th, 9th, 10th, and 11th Dec. 1878.	Black plastic clay with a few fragments of shells. ...	4·00	44·00	
33	11th December 1878	Compact black clay mixed with fine sand.	0·75	44·75	
34	11th, 12th, 13th Dec. 1878.	Black clay mixed with moderate sized sand.	3·30	48·05	
35	13th and 14th Dec. 1878.	Fine sand and dark earthy clay	1·35	49·40	

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—contd.

Number of Strata.	Dates.	Geological Strata.	Thick- nesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
36	14th, 16th, 17th, 18th Dec. 1878.	Fine sand, earthy clay less dark	5.30	54.70	(56.50) 1st gushing out of water. The in- terval of time between the 21st December 1878 and 2nd January 1879 was employed in clearing away the sand in order to ob- tain a larger dis- charge.
37	18th, 19th, 20th Dec. 1878.	Coarse clayey sand mixed with small gravel, conglomerates and ferruginous sandstones.	2.00	56.70	
38	20th, 21st Dec. 1878, and 2nd January 1879.	Coarse pure sand (same ma- terials as above).	2.50	59.20	
39	3rd January 1879...	Coarse whitish sand mixed with small gravel, very white clay and ferruginous sandstones.	0.90	60.10	
40	3rd, 4th January 1879.	White sandy clay	0.15	60.25	
41	4th, 6th, 7th, 8th January 1879.	White sand mixed with small gravel, ferruginous sand- stones, fragments of white clay.	5.79	66.04	(68.85) 2nd gush.
42	9th January 1879.	Grayish sand, small gravel, white friable sandstone, quart- zo-metallic conglomerates and ferruginous sandstones.	0.56	66.60	
43	10th ,, ,,	Blackish sand (same materials without the gravel).	0.80	67.40	
44	10th ,, ,,	Coarse sand and quartzo-metal- lic conglomerates.	0.50	67.90	
45	11th ,, ,,	Grayish sand, small gravel, me- tallic conglomerates and de- cayed wood.	0.70	68.60	
46	11th, 13th, 14th, 15th January 1879.	Gray sand, grits and metallic conglomerates.	0.50	69.10	
47	15th, 16th, 17th, 18th, 20th, 21st, 22nd, 23rd, 24th, 25th, 27th, and 28th January 1879.	Coarse sand, sand, small gravel, decayed wood, fragments of white and gray clay and me- tallic conglomerates.	2.40	71.50	
48	29th, 30th, 31st Ja- nuary 1879.	Very fine and pure gray sand...	0.90	72.40	
49	1st, 3rd February 1879.	Fine black and gray sand, frag- ments of clay, decayed wood and vegetable detritus.	1.20	73.60	

Table of Geological Strata of the Artesian Well bored in the Jardin d'Acclimatation at Pondicherry—concl'd.

Number of Strata.	Dates.	Geological Strata.	Thicknesses of Strata.	Progressive Depths.	REMARKS.
			M.	M.	
50	3rd, 4th, 5th, 6th, and 7th February 1879.	A moderate sized sand, grits, small gravel, decayed wood and iron ore.	4.20	77.80	
51	7th, 8th, 10th, 11th, and 12th February 1879.	Moderately gray sand, lumps of clay, grits, small gravel, decayed wood and iron ore.	0.60	78.40	(79.34) 4th gush.
52	12th, 13th, 14th, and 15th February 1879.	Moderately gray sand, grits, decayed wood, small gravel and iron ore.	1.12	79.52	

Drawn up by the Colonial Engineer, Chef du Service of Roads and Bridges.

A. CARRIOL,

The 24th March 1879.

Pondicherry.

On the 15th November, after thirteen days of work, a rise of water-level was found at a depth of 10.74 metres. The water-level, which was originally 2.80 metres below the level of the soil, rose to 1.27 metres. The water was of the same character as that of surrounding wells, the water-level of which remained stationary at 2.80 metres.

These first 10.74 metres (which gave a mean depth sunk of .82 of a metre per diem of ten hours of actual work) consisted of alternate layers of ordinary gravel mixed with clay, fine and very fluid sand, lumps of black plastic clay, bits of decayed wood, and of coarse blackish sand mixed with black clay, and were bored either by a rotating auger (*tarière*), or by means of a "soupape à boulet." This last implement produced the best results, especially in quicksand, during the whole course of operations.

From the 15th November to the 20th December, boring continued without interruption; the level of the rising water rose higher and higher; from 1.27 metres, which it had when first met with, it rose till it was not more than .95 of a metre below the surface of the ground on the 18th. It remained at this level till the 20th December, on which date at a depth of 56.50 metres, a gush of water was encountered.

This outflow showed itself on the night of the 19th. The temperature of the water was 31° centigrade, and its hydrostatic level rose .55 of a metre above the level of the ground. During the boring, the water rose and fell intermittently, varying between .40 and .44 of a metre. This was the result of the continuance of the operations. On the 21st December, the hydrostatic level rose to .99 of a metre and gave a discharge of 140 litres a minute. Work was carried on at this time in a stratum of coarse gravel mixed with clay and small gravel. The water-level remained stationary for some time; the discharge increased considerably, rising from 140 to 224 litres between the 21st and the 24th December. The temperature of the water was 34°, and on analysis by Mons. Cazalis, 1st Class Chemist of Marine, showed

the following composition, as embodied in the Proceedings of the Commission of the 28th December 1878:—

Sulphate of lime	0,1050	} Substances precipitated by soap and water.	
Carbonate of lime	0,0210		
Silica	.	.	.	.	.
Magnesia	.	.	.	.	.
Iron (traces of)	.	.	.	.	.
Chloride of soda	0,1800		
TOTAL						.	<hr/> 0,3060	

These proportions not constituting a perfectly drinkable water, though very useful for watering the garden, the Commission determined to carry on operations to a greater depth. The tubing was accordingly continued with pipes of the same diameter as at the beginning. From the 30th December, under the impetus given to the works, the hydrostatic level commenced to fall, and in consequence the discharge of water underwent the same diminution. From 1·28 metres which it had attained, there was not more than 1·005 of a metre on the 31st December, '83 on the 4th January 1879, and on the 6th (having attained a depth of 62·54 metres), the level was '01 below the level of the ground.

From the 6th to the 13th January, the works were continued and pushed on to 68·75 metres. On the 13th, a second gush of water showed itself, which rose at length to 0·40 of a metre above the ground, but the piping became more and more difficult. A deviation of '07 of a metre had already been noticed in the vertical projection of the column which caused friction at the bottom of the last pipe, the soupape à boulet continued to act, but the results were very poor. At one time, every effort that was made, could not overcome the resistance in sinking the column on account of the pressure of the sand against the sides. The situation was serious and very embarrassing. It was seen, moreover, that the hoop which protected the bottom of the first pipe was displaced, and that the "trépan" of the "soupape" struck it at every stroke and brought away fragments of it. It was necessary to use repeatedly the large trépan which entirely detached the hoop and ground it into small pieces. The crane which was lifted by the pressure of the jackscrews was successively charged with weights varying from 1,920 kilos to 5,070 kilos. Notwithstanding this pressure, the resistance was still great. The "soupape à boulet" continually brought up the débris of the hoop and the pipe to which it was rivetted; the work of boring was almost at a standing, and the crane continued to rise. It was then loaded with a total weight of 19,290 kilos. A small sounding probe was lowered down the tube, which penetrated to a depth of '55 of a metre in the ground and brought away traces of bluish clay. The boring was then at 68·81 metres, which showed the depth sunk during the day to be only '06 of a metre. The hydrostatic level which rose for a moment to 1·03 fell to 0·95, and, on the 16th January, was not more than '25 of a metre above the ground. It rose and fell, alternately, from '73 to '69 of a metre, and eventually fell down to '12 below the ground-level, while the tubes were not able to be driven in more than '67 of a metre in a week.

The works were proceeded with nevertheless, but the results were very poor. We were however, on the point of overcoming the resistance to the driving in of the pipe. When the column had passed the water-bearing strata, the water caused an opening between the exterior of the pipes and the ground penetrated. From that time the work became easier; resistance diminished, and the "soupape" having reached the coarse sand, operations became a great deal more satisfactory.

On the 3rd February, there was a third gush of water, the hydrostatic level of which rose to '38 of a metre above the level of the ground. The boring had then reached to 73·60

metres. This fresh gush of water, like the one which preceded it, made the sand flow back from 50 of a metre to 1.20 metres into the interior of the tube. The work continued by means of the small soupape à boulet, and we then attained a depth of 79.34 metres.

At length, on the 13th February, after penetrating a stratum of very fine sand mixed with grits and remains of decayed wood, the hydrostatic level which had remained at about the level of the ground rose to 52 of a metre, and continued under the impetus given to the work to rise gradually to 1.48 metres in twenty-nine days. This is the jet we now have. The water is very clear, does not taste bad, and boils vegetables perfectly. It marks 98 on the hydrometer. Its temperature is 34°30'.

The discharge of water was, on the 13th February, at 10 A.M., 140 litres; in the evening it was 268 litres; and to-day, the 20th March, it has reached to 666 litres a minute—a quantity more than sufficient to irrigate the Jardin d'Acclimatation. After several attempts to extract the bottom of the pipe, it was discovered that the force of the rising water brought up sand to the surface, and that the detachment had been effected spontaneously. The boring has reached to 79.52 metres. It took 89 days of 10 hours each of actual work. This gave an average per diem of $\frac{79.52}{89} = .89$ daily.

The following have been the general expenses:—

	F.	C.	F.	C.
Construction of the crane	1903	52	2570	55
Transport and setting up, &c.	662	03		
Value of 80m of pipes	2340	00	3420	00
Expenses of packing, freight and insurance	1080	00		
Hire for driving in the pipes	1630	12	1630	12
TOTAL			7620	67
			2570	55
			5050	12

If from this sum the cost of the crane be deducted, which was Fr. 2570.55, the real cost of the well will be only 5050.12.

This makes the cost of each running metre in boring $\frac{5050.12}{79.32} = 63\text{f. } 50\text{c.}$

This expenditure is really very small when we take into consideration the dreadful famine which raged through this country in 1877 and 1878 in consequence of want of water.

One can now assert with certainty after the success achieved in boring three wells within a radius of about 800 metres of each other, and at depths varying from 38.53 to 79.52 metres, that if the calamities which famines involve on the Coromandel Coast are not completely overcome, their disastrous consequences can be considerably mitigated by sinking artesian wells.

* * * * *

This being the first attempt at boring to such a great depth in this country, I have thought that, from a scientific point of view, it would be useful to have in France a complete collection of geological specimens of the strata penetrated. With this view, I have caused a case containing an extract from the register of borings with all the specimens and four bottles of the water now issuing from the well to be deposited in the Magasin Général. I think M.l'Ordonateur that this case should be forwarded to His Excellency the Minister of Marine and Colonies, who would probably make it over either to the School of Roads and Bridges or the School of Mines.

(Signed) A. CARRIOL,
L'Ingénieur, Colonial,
Chef du Service des Points et Chaussées.

APPENDIX II.

Experiences of Mr. C. Poulain in the boring at the Savana Filature. Extracted from "Travaux des Commissions Locales," (Commissions des Puits Artésiens). Pondicherry, 1877.

L'outillage, dont il est inutile de donner le détail est celui employé pour le sondage à la corde appelé *sondage chinois* avec quelques modifications facilitant le travail dans les terrains que nous avons rencontrés. Nous avons employé pour tuber notre trou de sonde un tuyau en cuivre rouge de 14 centimètres de diamètre intérieur et d'une épaisseur de métal de 0m 003m/m. La longueur de chaque tuyau variait de 2 m. 50 c. à 3 mètres. Ils sont réunis l'un à l'autre par un manchon de même métal et de même épaisseur fixé au moyen des rivets.

Un puits de service de 2 mètres de profondeur a été creusé et un échafaudage composé de 2 bigues et 1 traverse a remplacé la chèvre qu'il aurait fallu construire.

Tout étant prêt, le sondage a commencé le 18 février; nous nous sommes servi de la cuillère à soupape de Jobard. Nous étions dans cette couche de gros sable qui est très-employée dans le pays pour la fabrication du mortier. La profondeur était alors de 4 mètres, nous avions 50 centimètres de hauteur d'eau dans notre tube que nous descendions au fur et à mesure en le chargeant de gros poids de fonte et lui communiquant à force de bras un mouvement de va-et-vient au moyen d'un tourne-à-gauche formé de 2 pièces de bois à machoires boulonnées fortement sur le tuyau de tubage. Le travail marchait lentement, la quantité de sable ramenée étant très-faible. Les clapets s'engageaient souvent quoique nous ayons eu soin de garnir la charnière de ceux-ci d'un tube en caoutchouc au centre duquel passait la broche servant d'axe à ces clapets. De plus, l'écrou de retenue contre lequel il allait faire choquer le mouton à la montée pour opérer la fermeture des clapets, se détériorait. Nous fûmes obligé, plusieurs fois, d'en mâter la tête. Enfin, l'écrou se cassa, laissant remonter le mouton tandis que la cuillère à soupape restait au fond du trou. Nous n'étions alors fort heureusement qu'à 6 mètres de profondeur; ce qui permit de remener facilement la cuillère restée au fond. Nous travaillons toujours dans la même couche de sable mêlé de quelques cailloux roulés, les uns blancs tels que ceux que l'on trouve au grand-étang et autres noirs, ternes et quelques-uns ayant un reflet rappelant le chatoyement de ces pierres connues sous le nom d'œil-de-chat. Nous avons également ramené de cette profondeur quelques pierres à arrêtes vives, nullement roulées, ressemblant à des débris de basalte et d'amphybole. Quelques-unes avaient une apparence verdâtre. Nous réparâmes la cuillère à soupape, mais craignant un nouvel accident, nous construisîmes une soupape à boulet qui fonctionna admirablement jusqu'à la profondeur de 7 m. 40 c. où nous rencontrâmes une couche d'argile noire mêlée de même sable et de quelques cailloux. Au bout de quelques coups de sonde, nous ramenâmes des fragments d'argile noire qui formaient une couche compacte à en juger par l'effort qu'étaient obligés de faire nos hommes pour dégager l'outil. Le travail marcha encore lentement, nous étions déjà au 13 février. Nous ne ramenions à chaque coup de sonde que de fort petites quantités d'argile; nous pensâmes que notre outil gêné dans sa chute par une hauteur d'eau de près de 4 mètres, n'avait pas assez de poids. Nous suspendîmes alors, au moyen d'un assemblage à boulon sur les tirants de la soupape à boulet, un cylindre en fer de 5 centimètres de diamètre et 25 centimètres de longueur. L'outil pénétra alors plus profondément dans la glaise et en ramenait fort peu encore. Nous adaptâmes alors au couteau circulaire de la soupape à boulet le couteau en croix de l'outil de Collet de Reims, ce qui eut pour résultat de diviser cette partie du cylindre en quatre compartiments présentant chacun une surface d'adhérence bien supérieure à celle

existant précédemment. Le travail marcha un peu plus rapidement et le niveau de l'eau baissant dans le tube à chaque coup de sonde, nous arrivâmes le 14 février au soir à 7 m. 80 c. La glaise devenait plus compacte et ne contenait presque pas de sable, nous y remarquâmes quelques paillettes nacrées, ayant à peine un millimètre carré de surface. Il nous vint ensuite des débris de coquilles nacrées très-molles à l'état humide se feuilletant sous l'angle. Nous restâmes dans cette couche jusqu'au 16 vers midi; l'eau avait disparu totalement du tube dans la matinée, ce qui indiquait que la couche de glaise était parfaitement imperméable. La profondeur atteinte était de 10 mètres environ. Dans l'après-midi, l'eau reparut dans le tube, nous étions alors à 10 m. 28 c. et nous retirâmes du fond du sable quartzes, souillé d'argile noire. Après quelques coups de sonde, l'argile noire reparait. L'eau qui était remontée dans le tube jusqu'à 3 m. 50 c. de la surface, rebaisse et finit par disparaître; nous continuâmes nos forages en versant de l'eau dans notre tube et ramenant toujours de la glaise noire bien plastique, pure de tout mélange. Nous continuâmes ainsi jusqu'au 17 au soir, nous étions arrivé à la profondeur de 16 mètres. Le tuyau de tubago descendait difficilement quoique nous ayons augmenté les poids de charge et le nombre de nos hommes agissant sur le tourne-à-gauche. Notre chef sondeur s'aperçut alors qu'il se produisait dans le tube un bruit ressemblant à la chute d'un jet d'eau dans le fond. Il était presque nuit close, nous arrêtâmes le travail. Le lendemain matin, le même bruit se produisait, mais le soleil était encore à l'horizon, il nous était impossible de rien distinguer dans le tube. Nous essayâmes à manœuvrer le tourne-à-gauche, la résistance était grande nous remarquâmes que le bruit de jet d'eau augmentait; nous descendîmes dans le tuyau une lampe allumée, placée dans un petit seau qui nous avait servi à prendre des échantillons d'eau dans les moments de repos.

Nous découvrîmes alors une fissure qui s'était produite à la soudure d'un des joints de notre tuyau. Nous décidâmes immédiatement qu'il fallait procéder au levage du tube pour en faire la réparation: après des efforts énormes au moyen de levier et de *Jack screw* le tuyau céda et vint avec facilité; mais une longueur de 11 mètres était restée dans le fond du trou de sonde et son extrémité supérieure était à 5 mètres en contrebas du sol. Nous fîmes aussitôt creuser notre puits de service jusqu'au niveau de la première couche aquifère; au moyen de plongeurs, nous coulâmes 2 m. 10 c. de couronnes en terre cuite, notre tuyau se trouva ainsi dégagé de 60 centimètres du fond du nouveau puits. Pour faciliter le travail des forgerons qui devaient redresser le tuyau et y placer un système d'arrachage, nous installâmes deux pompes à incendie du modèle de la ville de Paris. Enfin, le 28, tout le mal était réparé, nous avions de plus vidé le tube de sondage qui s'était rempli jusqu'au fond et nous étions redescendu au point où l'accident nous avait surpris. Nous sommes toujours dans la même couche d'argile noire et compacte, l'eau a complètement disparu le 28 à midi et nous sommes à 16m. 58c. Vers la fin de la journée, l'eau reparait un peu, nous espérons que c'est une couche de sable, nous donnons quelques coups de sonde, nous ramenons toujours la même argile, l'eau cependant, semble monter encore, nous en sommes inquiet, nous rappelant notre premier accident. Le tube est dur à manœuvrer; nous parvenons toutefois à le descendre de quelques centimètres en donnant un léger mouvement de va-et-vient; un dernier coup de sonde nous donne un peu de sable mélangé à l'argile. Il était presque nuit, on arrête le travail. Quel ne fût pas notre étonnement le 1^{er} mars au matin, de trouver notre tube plein et débordant légèrement à une hauteur de 1 mètre en contre-bas du sol! L'écoulement est très-faible et n'est appréciable que lorsqu'on est près du tube nous arrêtâmes alors la descente du tube et nous fîmes sonder jusqu'au soir en travaillant au-dessous de celui-ci. L'outil même se prenait quelquefois, en remontant, au rebord inférieur du tuyau. Toute cette journée, nous avons ramené tantôt de l'argile pure, tantôt de l'argile mêlée de sable gros et fin. L'écoulement de l'eau, dans les moments de repos, continue, il augmente légèrement à mesure que le travail avance; le 2 au matin, le tube est plein et déverse un filet encore très-mince à un mètre au-dessous du niveau du sol.

Nous faisons vider le tuyau au moyen d'un petit seau jusqu'à la profondeur de 2 m. 50 c. au-dessous de la surface, l'eau met une demi-heure pour remonter à son niveau primitif; nous faisons descendre le tube en manœuvrant le tourne-à-gauche, il descend facilement d'un mètre; l'eau coule avec un peu plus de force, l'orifice d'écoulement étant abaissé. Nous rivons un tuyau de 1 m. 20 c. et nous ajoutons un autre tuyau de 1 m. 20 c. dont le joint est fait avec de la glaise et nous arrêtons le travail après avoir donné quelques coups de sonde qui nous ramena de gros sable quartzeaux dont quelques grains sont brillants et hyalins d'autres au contraire opaques, variant du blanc au jaune-rougeâtre.

Le 3 au matin, nous constatons que l'eau a monté dans le tube et s'est arrêtée à une hauteur de 30 centimètres au-dessus du niveau du sol; nous enlevâmes le tuyau supplémentaire et nous continuâmes le travail; la sonde nous ramenait du gros sable mêlé de sable fin de couleur grisâtre; vers 10 heures du matin, l'écoulement était devenu appréciable. Nous recueillîmes le produit du déversement dans un seau jauge de 10 litres; il se remplit en 2 minutes; nous sommes à 19 mètres environ de profondeur. Le soir, le même seau a été rempli en 1' 45" sous les yeux de la Commission des puits artésiens qui avait bien voulu se transporter à l'établissement *Savana*, à la suite de sa première séance; le 4 au matin, l'eau est complètement claire et potable; quelques personnes la trouvent ferrugineuse; c'est à vérifier.

Le travail a été suspendu toute la journée du 4 qui était dimanche. L'eau a coulé toute cette journée, toute la nuit et le lendemain 5 mars, jusqu'à midi, et elle se déversait en un filet de l'épaisseur du petit doigt à 45 centimètres au-dessus du niveau du sol environnant. Nous enlevâmes le tuyau supplémentaire que nous avions placé pour vérifier le niveau hydrostatique et nous rivâmes un nouveau tuyau de 1 m. 80 c. m. de longueur. Nous repr. nous la sonde et nous travaillons toujours au-dessous du niveau inférieur du tuyau, ce qui occasionne des éboulements souterrains qui maintiennent invariablement la sonde à 70 ou 80 centimètres en contre-bas de notre tuyau. Le sable qui vient, contient quelques paillettes brillantes comme précédemment. Nous descendons notre tuyau d'un mètre, ce qui met à 19 m. 58 c. m. la longueur totale du tuyau. Pendant que nous continuons à sonder, la Commission des puits artésiens vient faire sa seconde visite. Nous faisons donner quelques coups de soupape à boulet qui ramena à chaque fois le même sable. Nous procédons ensuite sous les yeux de la Commission à la vérification de la profondeur du trou de forage au moyen d'un plomb de sonde; l'opération a accusé une profondeur de 21 mètres. Nous avons remarqué que l'eau, depuis la descente du dernier mètre de tuyau, était moins abondante et par suite montait plus lentement. Le tuyau été descendu alors environ de 30 centimètres par un mouvement de va-et-vient imprimé au tourne-à-gauche. Les opérations ont été suspendues le soir et ajournées au moment où nous pourrions avoir des tuyaux pour les continuer.

Voici les remarques que nous avons faites sur la qualité de l'eau: pendant la journée du 4 mars elle est très-limpide et dégage des bulles gazeuses que nous supposons être de l'acide carbonique, n'ayant pas les moyens de le constater. Sa saveur est franchement ferrugineuse. Elle prend, par l'addition d'une solution de tannin, une teinte violet-noire, claire; elle donne un léger précipité de chlorure d'argent avec la solution d'azotate d'argent. Nous en avons évaporé un litre qui a laissé un assez fort résidu. Conformément au désir de la Commission, nous avons fait remettre le 6 mars à M. le Pharmacien de 1^{re} classe de la marine Castaing, membre de la Commission des puits artésiens, le susdit résidu en y joignant 6 litres environ de l'eau du puits de sondage et les échantillons de terre que nous avons recueillis à diverses profondeurs.

Le 6 mars, l'eau continue à couler légèrement du tuyau dont l'orifice supérieur est à 1 mètre en contre-bas du sol. L'eau ne s'est pas éclaircie encore à midi; en la filtrant au papier gris, elle devient très-limpide. Dans la soirée, elle s'éclaircit complètement, l'écoule-

ment est à peu près le même que la veille. Tels sont les détails du travail auquel nous nous sommes livré jusqu'à présent dans la recherche d'une source artésienne à l'établissement *Savana*. Nous craignons le reproche d'avoir été peut-être un peu minutieux, mais nous avons à cœur d'éclairer la Commission d'une manière aussi complète qu'il était en notre pouvoir, en présence surtout de la façon gracieuse dont son président a bien voulu proposer de nous aider en nous procurant les tuyaux nécessaires pour continuer notre expérience.

Signé: C. POULAIN,
Industriel.

Pondichéry, le 6 mars 1877.

Nous avons continué, lorsque nous en avons eu les moyens, le fonçage du puits de *Savana* dont notre dernière note accusait une profondeur de 19 mètres 58 centimètres. A 27 mètres, nous avons rencontré une couche de glaise noire (Regur) dans laquelle nous avons pénétré de 5 mètres environ; mais là, un nouvel accident nous a arrêté: notre tuyau de tubage s'est aplati, puis rompu lorsque nous l'avons relevé. Cet accident était dû à plusieurs causes: l'applatissement a été produit par la poussée du sable extérieur d'une part, et par un effet de succion qui s'est produit dans le tuyau lorsqu'on retirait la soupape à boulet alors noyée dans une espèce de vase demi-fluide produite par l'argile délayée dans l'eau et qui a fait faire en quelque sorte office de piston à la dite soupape. Le mode de descente de tuyau qui avait été employé, c'est-à-dire un mouvement de va-et-vient répété a aussi sa part dans la cause du résultat fâcheux que nous subîmes. Nous ne nous décourageâmes pas et nous recommençâmes à nouveau à deux pieds plus loin le fonçage du tuyau que nous venions de retirer. Nous sommes aujourd'hui arrivé à 22 mètres et nous descendons notre tuyau au moyen d'une presse à vis qui agit sur lui dans le sens vertical. Nous avons dû aussi faire éprouver une extrême fatigue au tuyau dans l'opération du fonçage parce que nous n'élargissions pas au moyen d'un alésoir notre trou de sonde avant de l'y insérer et que l'argile se dilatant au contact de l'eau l'enserrait d'une façon très-sensible. En résumé, Messieurs, ces accidents sont causés par un défaut de pratique, ayant été appelé pour la première fois de notre existence, et sans aucun guide de l'art du sondeur, à établir un puits artésien. L'expérience acquise et un excellent ouvrage sur la question, qui a été mis à notre disposition par M. Amalric, un des propriétaires de *Savana*, nous permettront à l'avenir, nous l'espérons, d'éviter ces contre-temps. Enfin, Messieurs, nous pouvons le dire sans crainte d'être contredit, l'expérience de *Savana* a eu plusieurs résultats pour nous: 1° celui d'avoir attaché tout le monde à cette question d'intérêt général; 2° d'avoir établi le premier jalon de la nature des sols à une certaine profondeur et 3° enfin surtout, d'avoir disposé d'une façon favorable, par un commencement de preuve, les personnes haut placées qui devaient décider du sort du projet que nous avions présenté au Conseil colonial. Nous continuons notre travail et nous en rendrons compte au fur et à mesure de son avancement avec la conviction intime que nous aurons bientôt, toutes choses égales d'ailleurs, le plaisir de vous annoncer notre complète réussite.

C. POULAIN.

Pondichéry, le 19 juin 1877.

Depuis notre dernière communication, des travaux urgents à l'établissement ne nous ont pas permis de poursuivre d'une façon continue notre sondage. Nous vous disions dans cette note que, dans notre second sondage, après l'accident arrivé au premier, nous étions parvenu à la profondeur de 22 mètres, c'est-à-dire, à la couche de sable aquifère rencontrée précédemment et qui nous donnait de l'eau à 40 centimètres au-dessus du niveau du sol. Cette fois l'eau de cette même nappe a atteint un niveau hydrostatique de 0, 50 centimètres au-dessus

du sol, soit 10 centimètres de plus que précédemment. Nous attribuons cette différence à ce que notre tuyau était plus étanche, ayant pris pour le nouveau sondage la précaution de souder à l'étam tous nos joints de tuyau rivés. Nous avons continué le fonçage dans ces sables et nous avons comme précédemment trouvé à 27 mètres de profondeur une couche de glaise que nous avons traversée. Son épaisseur est de 6 mètres environ. La sonde a rencontré ensuite, c'est-à-dire à 33 mètres de profondeur, une couche de sable gris, d'une finesse extrême, fluide et même visqueux, qui a monté rapidement d'un mètre dans le tuyau de retenue et a engagé une première fois notre soupape à boulet que nous avons retirée avec grande peine en nous servant de la traction produite par un treuil double. L'eau qui jusque-là s'était maintenue à une assez grande profondeur, monta jusqu'au niveau du sol : c'était une nouvelle nappe qui se faisait jour. Après quelques coups de sonnette, notre outil a pénétré plus profondément et une poussée subite de 1 mètre 60 de sable se produisant dans le tuyau, la soupape s'est trouvée très-fortement engagée et a résisté aux tractions les plus puissantes que nous ayons pu exercer. Nous introduisîmes alors une soupape à boulet d'un plus petit modèle, n'ayant que 0 mètre 06 cent. de diamètre et qui, pouvant fonctionner dans l'intervalle laissé libre par le câble de la grande soupape, nous permit de ramener peu à peu un volume de sable équivalent à 50 centimètres de hauteur dans le tuyau. C'est le plomb de sonde qui nous a fourni cette donnée. Nous nous aperçûmes alors que le couteau circulaire de cette petite soupape entamait notre câble au fond et en ramenait des fragments à l'état de filaments délayés dans la masse du sable. Nous construisîmes à la hâte avec un bout de tuyau une soupape à clapet de plus petite dimension encore, soit 0 mètre 04 cent. de diamètre, munie d'un couteau circulaire en bois et d'un clapet de cuir chargé d'une plaque de plomb. Nous ramenâmes fort peu de sable et il contenait toujours des filaments de chanvre. Pensant que ces filaments provenaient de l'opération précédente, nous persistâmes à nous servir de ce nouvel outil. Après vingt heures de travail, les filaments venaient toujours et en grande abondance. Craignant de détériorer notre câble, nous renonçâmes donc à ce moyen de dégager notre outil.

Nous fîmes alors descendre dans la colonne de retenue, à 32 mètres de profondeur le tuyau en toile, armé de sa lance, d'une de nos pompes à incendie, au moyen de laquelle nous injectâmes vivement au fond du sondage une forte quantité d'eau qui produisit un courant ascensionnel ayant assez de vitesse pour ramener de cette profondeur une grande quantité de sable fin. Au bout d'une heure, nous jetâmes le plomb de sonde qui accusa une profondeur de 33 mètres 50. Nous soulevâmes alors de 30 centimètres notre tuyau de retenue en faisant agir en sens contraire notre presse à vis et le tuyau monta sans effort. En même temps un homme imprimait au câble des mouvements de torsion et de fouet, l'outil se trouva dégagé. Le câble n'a éprouvé qu'un peu d'éraîlement dans une partie; les filaments provenaient principalement de l'extrémité libre de l'attache. Cet accident nous a mis aux prises avec l'un des cas les plus communs dans les terrains éboulants et fluides du genre de ceux que nous traversons. L'eau se maintient à 90 centimètres au-dessus du sol, et à ce point elle ne donne pas d'écoulement. Nous avons goûté l'eau de cette dernière nappe, elle nous a paru bonne.

Cette couche de sable n'a qu'un mètre d'épaisseur; elle ne pouvait donc nous fournir un écoulement important. Nous trouvâmes ensuite une nouvelle couche de glaise, toujours de la même nature que les précédentes c'est-à-dire noire, plastique, compacte. Quelques rares cailloux noirs et schisteux comme précédemment ont été aussi ramenés par la sonde. Le niveau de l'eau s'est abaissé dans la colonne de retenue aussitôt que celle-ci a pénétré dans la glaise. L'épaisseur de celle-ci n'est que de 2 mètres environ; il nous est venu ensuite du sable siliceux, à gros grains, souillé d'un peu de glaise; nous sommes à 36 mètres 50 de profondeur et l'eau se tient à 1 mètre en contrebas du sol au moment où nous terminons cette note.

C. FOULAIN.

Pondichéry, le 20 Juillet 1877.

Le dernier compte-rendu de nos essais s'arrêtait à la profondeur de 36 mètres; nous étions alors dans des sables à gros grains souillés de glaise. A 37 mètres, nous trouvâmes une argile moins noire que celles rencontrées précédemment, sèche et contenant des grains de concrétions calcaires variant de 1 à 5 millimètres cubes et d'autres un peu plus gros. Cette couche d'argile contenant parfois un peu de sable, tantôt mêlé dans la masse, tantôt par bandes minces, a continué jusqu'à 45 mètres, soit donc 8 mètres d'épaisseur pour cette couche imperméable. Notre sonde ramena ensuite de la même glaise mêlée de cailloux roulés, la plupart, de la grosseur d'un pois, les uns blancs, les autres noirs, d'autres un peu plus gros. Puis, l'argile disparut et il nous vint de gros sables avec les mêmes cailloux dont quelques-uns, de quartz bien pur et hyalin tels que ceux que l'on trouve au Grand-étang dans le *Ravin des chauves-souris* et ailleurs et que quelques personnes ont fait tailler et monter en bijoux; à cette profondeur, l'eau a atteint près d'un mètre audessus du sol et a déversé légèrement quelques minutes seulement, pendant le travail, puis est redescendue à 70 centimètres plus bas,

A 46 mètres les cailloux deviennent plus rares, le gros sable est mêlé de sable fin, gris, fluide, du genre de celui rencontré précédemment à 33 mètres. Le travail devient très-lent quoique nous nous servions d'un treuil simple pour la descente et la montée de notre outil. L'élasticité de la corde augmentant avec sa longueur (46 mètres) rend la manœuvre moins précise et plus pénible. Le tuyau descend difficilement; nous sommes souvent obligé de le soulever pour le descendre ensuite. A mesure que nous pénétrons dans cette couche, les cailloux deviennent de plus en plus rares; les grains de sable sont très-gros et presque entièrement composés de débris de quartz hyalin de 2 à 3 millimètres cubes de volume environ. L'eau, pendant les moments d'arrêt, monte très-lentement et s'arrête à 30 centimètres au-dessus du sol. Nous étions à la profondeur de 46m 50c lorsque la sonde nous ramena quelques petits débris d'argile blanche, en partie délayés dans l'eau; nous pûmes cependant en trouver un de la grosseur d'une noisette qui nous a permis d'en examiner les caractères qui sont les suivants: elle ne fait pas effervescence avec les acides, happe fortement à la langue et prend un poli admirable sous le frottement de l'ongle, c'est du kaolin. Les cailloux de quartz et les quelques débris d'argile indiquent que l'alluvion les a enlevés aux terrains tertiaires.

A 47 mètres, le grain du sable est moins gros que précédemment, il ne contient presque plus de cailloux roulés; à 48 mètres, le sable de rivière est un peu mêlé de sable fin ressemblant au sable de mer, il vient encore quelques fragments d'argile blanche. Puis les sables alternent, tantôt fins, tantôt gros; nous y remarquons des débris d'argile calcinée noirâtre et des fragments ressemblant à la brique du pays; nous hésitions cependant encore à croire à la présence de briques lorsque la sonde nous ramena de petits tessons de poterie commune; (nous donnons ce dernier renseignement sous toute réserve, car il peut se faire qu'ils aient été projetés du sol.) Nous étions alors à 49m 90, l'eau se tenait à 50 centimètres au-dessus du niveau du sol quand tout-à-coup, à la suite d'un coup de sonde, elle monta très-rapidement et déversa au-dessus du tube de retenue dont l'orifice était à près d'un mètre au-dessus du niveau du sol. Nous fîmes suspendre le sondage dans le but de ne pas contrarier cette nouvelle nappe qui semblait se faire jour espérant qu'elle deviendrait spontanément abondante. Nous remarquâmes, pendant l'écoulement qui dura environ 5 à 6 minutes et que nous estimons supérieur à 10 litres par minute, que l'eau avait un mouvement alternatif de montée et de descente dans le tuyau: quand l'écoulement cessa, l'eau baissa rapidement. Nous fîmes alors donner un coup de sonde qui ramena du gros sable mêlé de boulettes d'argile noire de la grosseur d'un pois, puis toujours du sable tantôt fin, tantôt à gros grains et par fois les deux sables mélangés, souillés d'un peu d'argile noire délayée.

A 51 mètres, la sonde nous ramena des débris de psammite friable et teintée par de l'argile

ocreuse, jaune et mêlés de sables, de cailloux roulés et de quelques parcelles de calcaire dur d'un blanc grisâtre. L'argile ocreuse jaune teinte les sables et l'eau qui est fortement jaunâtre. A ce moment, le travail cesse d'avancer en profondeur quoique la soupape revienne chaque fois entièrement pleine de sable. Celui-ci monte dans le tuyau dont la longueur totale est de 52m 68 et le plomb de sonde n'y accuse qu'une profondeur de 51m 75. Ces sables semblaient inépuisables; après deux jours entiers de travail, nous étions toujours au même point; enfin le troisième jour la poussée du sable s'arrêta et l'outil put descendre à la profondeur de 52m 68. L'eau monta au fur et à mesure que nous dégagions les sables et elle déversa au-dessus de notre tube par tous les trous de rivet avec une certaine force; l'extrémité supérieure de notre tuyau était alors de niveau avec le sol environnant. Un petit accident arrivé à notre soupape à boulet nous obligea de suspendre pour deux heures notre travail. L'eau coula et sembla augmenter un peu et de jaunâtre qu'elle était, elle devint assez limpide. La soupape étant réparée, nous continuâmes à dégager et il nous vint deux ou trois fois du sable à gros grains noirâtres, puis des débris de grès ferrugineux (psammites) de couleur brun-foncée, moins friable que précédemment, mêlés dans la masse de sable blanc à gros grains légèrement souillé d'argile ocreuse jaune. L'eau augmenta sensiblement pendant le travail que nous arrêtâmes à 6 heures du soir; elle coula toute la nuit suivante et le matin elle se trouva d'une limpidité parfaite. Nous recueillîmes le produit de cette source dans un vase jaugé, nous trouvâmes que le débit était de 48 litres par minute. (10 Septembre 1877, 8 h. matin.)

Voici les remarques que nous faisons sur l'eau, elle est bonne au goût, sauf une saveur métallique très-légère qui tend à diminuer au fur et à mesure de l'écoulement; le nitrate d'argent y produit un léger nuage opalin et le tannin n'y donne aucune coloration. La température de l'eau à l'orifice du sondage est de 33 degrés centigrades. Le point de déversement actuel est de 30 centimètres au-dessus du niveau du sol environnant.

Nous continuons à dégager le fond du trou de sonde dans l'espoir que le débit augmentera et nous avons fixé notre tuyau pour l'empêcher de descendre plus bas.

Une seconde expérience faite dans la même journée accusa un débit de 66 litres par minute. Le lendemain (11 Septembre) à 8 heures du matin, le débit est de 90 litres par minute au moment où nous terminons cette note; nous conservons l'espoir d'une nouvelle augmentation.

C. POULAIN.

Pondichéry, le 11 Septembre 1877.

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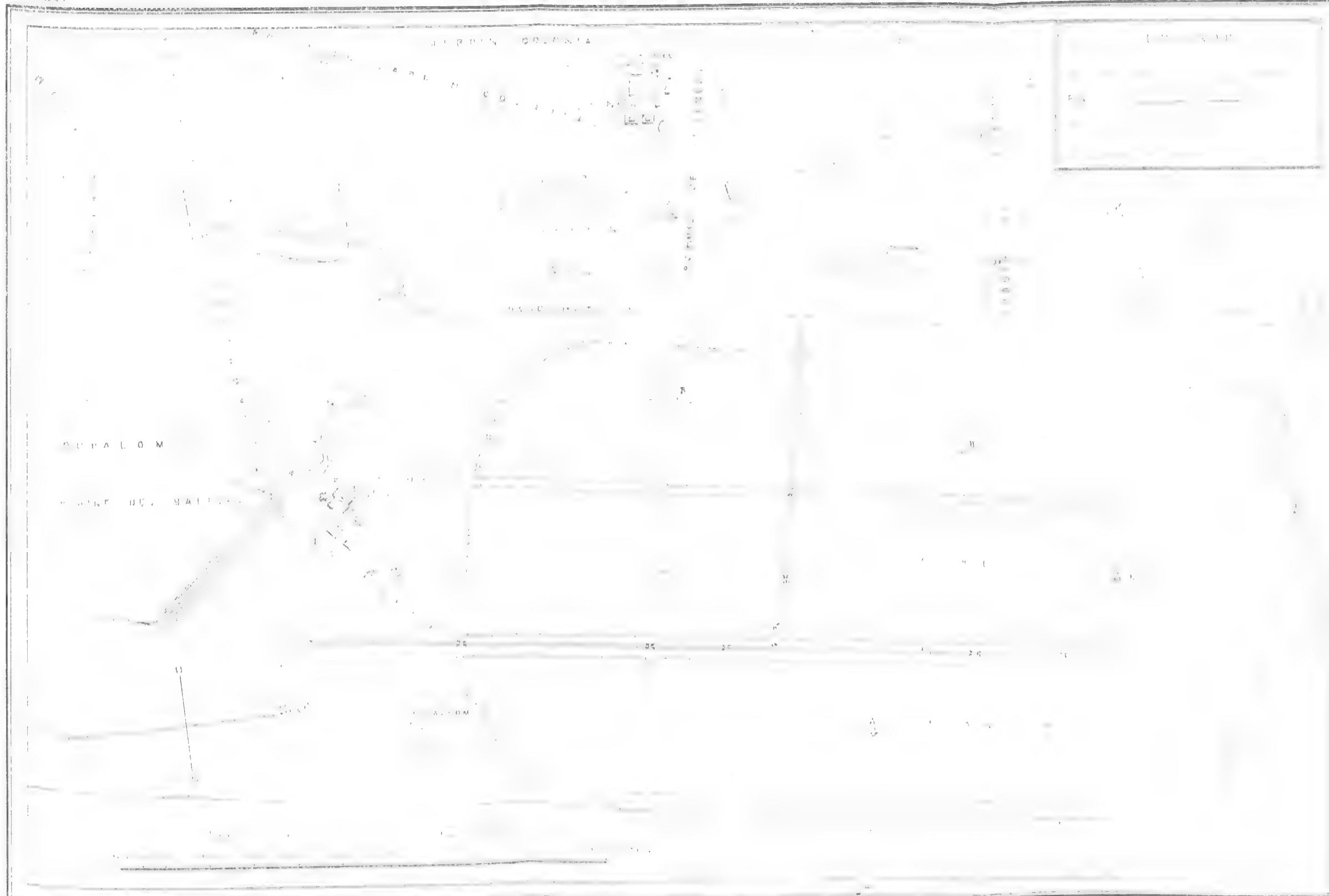
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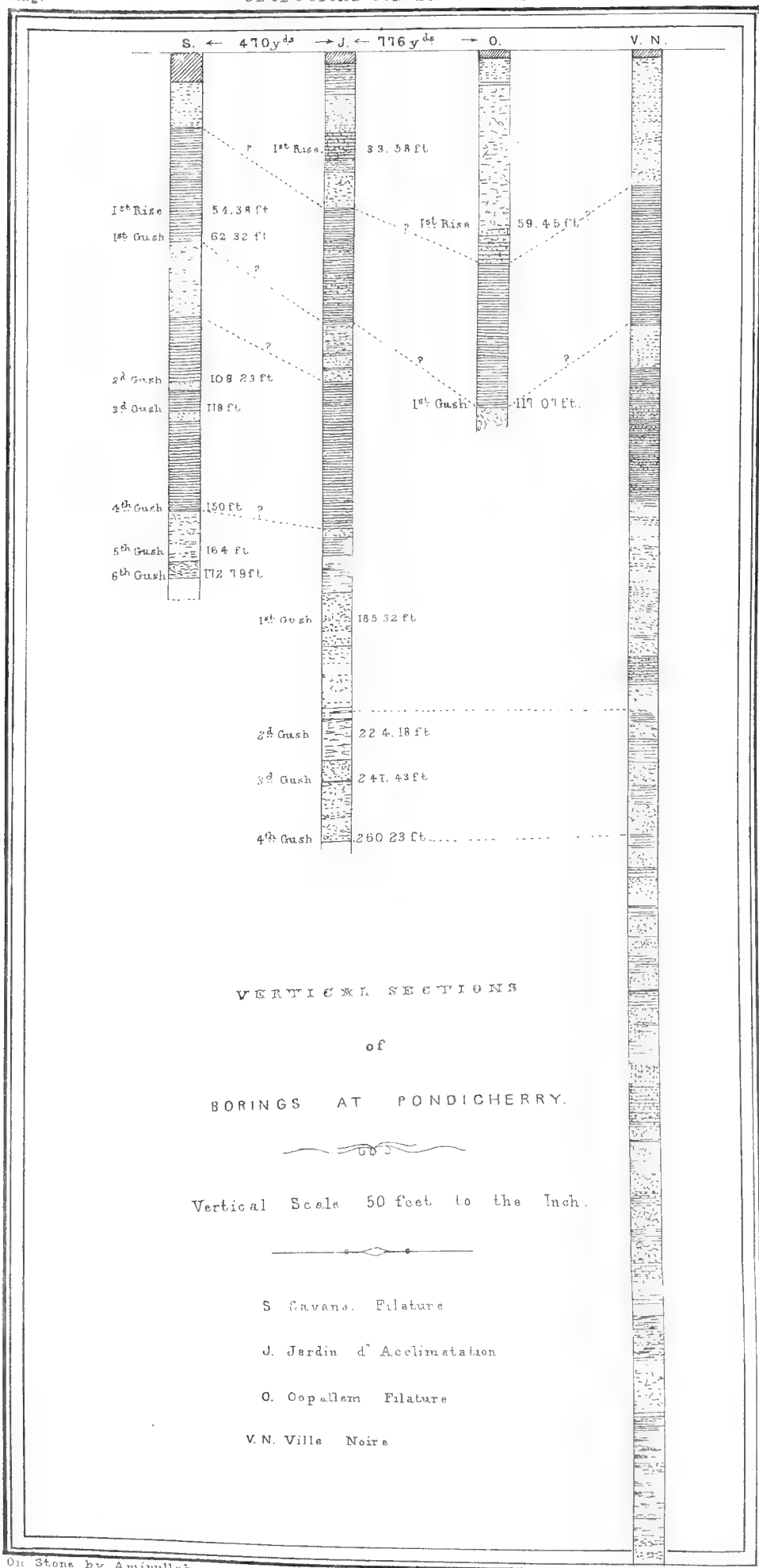
Botanist to the Kurum Field Force.

Stibnite (antimony sulphide) from Embinpilly on the Godavári.

P. VANSTAVERN, Esq.



PLAN DE LA VILLE DE PONDICHERY ET DE SES ENVIRONS.



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Abhandlungen zur Geologischen Specialkarte von Elsass-Lothringen, Band I, pts. 1-4, and II, pt. 1, with Atlas (1877 and 1879), 8vo, Strasbourg.

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RECORDS
OF THE
GEOLOGICAL SURVEY OF INDIA.

Part 3.]

1880.

[August.

THE KUMAUN LAKES, *by* W. THEOBALD, *Deputy Superintendent, Geological Survey of India.*

I cannot better preface my own notes on the Kumaun lakes, than by briefly advert to the views regarding their origin, propounded by my colleague Mr. Ball in the Records of the Geological Survey, Vol. XI, part 2, page 174; since differing so essentially, as I do, from them, it will be more convenient to specify at the beginning wherein this divergence of opinion consists, than to break the thread of my own description by constantly-recurring allusions to Mr. Ball's paper.

I make no affectation of approaching the discussion of the vexed question of the origin of the Kumaun lakes without any bias for any particular theory, since believing, as I do, in the strongly presumptive universality of glacial conditions during the great ice age, the result of cosmical rather than local causes, it would be absurd in me to disavow any expectation of finding traces of such conditions within the Himalayan region, of all others, or to deny that such conditions may not be held to afford a plausible *primâ facie* explanation of the origin of these lakes, deserving of all our respect, till it can be demonstrated that such a presumption is erroneous. Such an error, supposing it to be one, is, or should be, very capable of disproof, and I understand Mr. Ball's paper to be such an attempted disproof, but, in my opinion, an unsuccessful one.

The Kumaun lakes have so many points of resemblance in common, both as regards elevation, physical surroundings, and geographical arrangement, that it seems not unreasonable to assume a common origin for them all, so that I shall attach less importance to the elucidation of the history of those presenting obscure features, than to the endeavour to establish satisfactorily the origin of one or more of them; and I herein differ from Mr. Ball, in that, whilst he can discern no conclusive proof of glacial action in any of those visited by him, I consider

the case fairly, not to say strongly, made out as regards some, and capable of being extended by analogy, and in default of any sufficient reason to the contrary, to all.

Mr. Ball (p. 175 *l. c.*) commences by dividing the Kumaun lakes into three classes "having certain features mutually in common," but unfortunately without specifying what these features are; an omission which must be my excuse if I fail in consequence to do justice to my colleague's views on the subject. Passing to the consideration of Naini Tál (of which a pretty lithographed sketch is given) Mr. Ball seeks to controvert the views of those who attribute a glacial origin to its basin, but quite unsuccessfully, I think. Whether this lake really lies in a true ice-cut basin or basins, is certainly not established or likely to be so by actual proof, unless the lake is ever drained, a contingency which may be dismissed from present consideration, though if Mr. Ball's section of its basin represents the general contour of its bottom, and not the contour along a single line only, there is the strongest presumption in favour of its glacial origin. I do not, however, think it necessary now to dwell at any length on Mr. Ball's speculations as to the probable nature of the bottom, but there is one remark of my colleague touching the mode in which the rock basins (supposing them to exist) have been produced, which indicates so absolute a divergence from the current ideas respecting the *modus operandi* of ice action, that I do not like to pass it without remark. Mr. Ball's words are (p. 176 *l. c.*) "supposing it to be so, the twin basins might be readily explained by the hypothesis that they had been successively excavated by the retreating end of a glacier." This is perfectly unambiguous as far as language goes, but does Mr. Ball really suppose that a glacier ever moves backwards, and if not, then what does he mean by the above words?

A glacier does its work by its weight and momentum; its movement is solely *forwards*, not necessarily downwards, but simply forwards, and away from the direction of its source. The "retreating end" of a glacier, therefore, cannot excavate in any degree, or add in its retreat, to the work it had already performed in its advance; since the word "retreat" does not involve here any sense of *retrograde motion*, but simply a contraction of the dimensions of the glacier induced by the operation of climatal causes. As the end of a jet of water *retreats* as the pressure under which the jet issues is diminished, without, however, the particles which compose the jet losing their forward motion (though its amount may be reduced), so it is with a glacier, and I am therefore at a loss to know whether, in the passage quoted, my colleague's words correctly express his meaning.¹

I do not consider either that Mr. Ball has been particularly felicitous in his efforts to dispose of the argument adduced by Mr. H. F. Blanford for the glacial origin of the lake, from the peculiar shape of the basin, and the character of its sides, unbroken by subordinate ridges and spurs.

¹ Mr. Ball may perhaps be credited with the meaning his words would suggest to most of his readers—that the upper basin had been cut after the glacier had retreated from its position of maximum extension.—H. B. M.

Mr. Ball observes:—"It is true that there are no subordinate ridges and spurs, but such is not uncommonly found to be the case, where valleys run with the strike between hard beds, bounding softer ones, which have been eroded to form the valleys." The picture here drawn is suggestive of some great synclinal valley in Vindhyan sandstones, or in some similar group characterised by the parallelism and unbroken character of its beds, and there are doubtless many valleys which might have 'sat for the portrait,' but the entire force of the argument, as here used, depends on its applicability to the Naini basin. Of course, by introducing it in this connection, Mr. Ball implies that it is *so* applicable,—a view which I am wholly unable to coincide in. Mr. Ball, however, having created the impression which the above sentence is calculated to convey, nowhere else lays special stress on the parallelism of the strata bounding the basin, but speaks of them as in places "much contorted and broken," and of the limestones "near the dépôt" forming "irregular lenticular masses, not as beds." The fact is, the valley wherein Naini Tál nestles is surrounded by rocks, varying greatly in structure, such as splintery schists, and massive limestones, which agree in one character only, that of being very disturbed, as regards their stratigraphical arrangement, and much crushed and mechanically disintegrated as regards their petrological condition. This last condition (certainly one not unfavourable to the production of spurs by denudation) causes the hill sides to be much marked by debris (landslips perhaps Mr. Ball would say), washed down over them, but in the shallow road cuttings along the 'Mall,' the true arrangement of the strata may be seen, not as might be inferred from Mr. Ball's words, with a surface-plane and strike, coinciding with the axis of the valley, but revealing highly disturbed beds, with their ends truncated at various angles by the surface. Opinions may differ as to the value of the evidence in question, but the stratigraphical idea which Mr. Ball's words convey is certainly not that most obviously indicated on the ground.¹

Mr. Ball also alludes to "the rigid trap axis" of the hill, but this feature I consider no less suppositions than the implied parallelism of the beds bounding the lake. I was much surprised, after what I had read of the lake, to see so little trap in its vicinity, but much of the rock in the district which might be so termed in a petrological sense, I should prefer to regard as an integral member of the schist group. Beds of this character may occur in the range in force, but to speak of them as "trap" without further comment, is, I think, likely to mislead, especially in helping to confuse their relationship with the eruptive trap, properly so called, so largely developed about Bhim Tál and Malwa Tál. Mr. Ball, moreover, does not very clearly explain in what precise way the presence of either bedded or eruptive trap confers rigidity on the range in question, and in default of a fuller exposition of Mr. Ball's views on the subject, I am unable to recognise a greater amount of "rigidity" in the hills about Naini Tál, than in any other hills in this or any other district. Did the ranges environing Naini Tál consist

¹ To most geologists Mr. Ball's words would probably suggest a valley of erosion on a broken anticlinal flexure: a condition compatible with what he claims for the case and with the facts adduced against it in the text.—H. B. M.

of soft sands and clays banked up against a "rigid trap axis," I could appreciate the dynamical appropriateness of the expression, but not so, where the ranges consist of schists and massive limestones, and the very existence of a marked or strongly differentiated axis of a more rigid character is, to say the least, a matter of the purest supposition.

Equally is Mr. Ball at variance both with Mr. H. F. Blanford and myself regarding the nature of the barrier at the outfall of Naini Tál: Mr. Blanford and myself both regarding it as a moraine, whilst Mr. Ball terms it a landslip; and I may here remark that to "landslips" (so far as I can gather) all the Kumaun lakes are, in Mr. Ball's opinion, due.

As regards the particular case of Naini Tál, it may be seriously objected to Mr. Ball's view, that the barrier is not placed where the sides of the valley are steepest, nor is the slope sufficient to suggest such a cause. A general idea of the objection here taken by me, may be gathered by referring to the sketch of the lake given in Mr. Ball's paper; but it requires a personal knowledge of the ground to realize how much bolder the slopes are at other parts, where no obstructive landslips have descended, than at the actual outfall. It may be suggested that the very descent of the "slip" has itself lowered the slope, and modified the profile of the neighbouring ground, but I do not think such is the case either here or anywhere else, and I merely allude to the notion, to prove that it has not escaped consideration. A few words will not be here out of place, touching the effects produced by a 'landslip' as contrasted with those due to a 'moraine.'

A landslip in its proper and original sense, is a somewhat rare phenomenon, (depending on certain conditions of surface, subsoil, and drainage), such as the 'undercliff' in the Isle of Wight, and such cases as quoted in White's 'Selbourne', but which are rare in the Himalayan region, though not unknown in the Salt-range. The term is, however, also applied to one of the commonest phenomena in hilly regions, the descent from a steep hill or cliff, of a mass of rocky materials, detached partly by frost perhaps in the first instance, partly by water and partly by gravity; the initial movement where the mass is considerable being possibly in some cases due to an earthquake. This being the sort of phenomenon considered by Mr. Ball as being the cause wherefrom all the Kumaun lakes have originated, it is necessary carefully to consider how far the conditions present in such cases resemble or differ from those connected with moraines, and whether they are adequate to the production of the results attributed to them. Such 'slips' as I now allude to may be broadly divided into two classes, namely, those which consist mainly of rocky fragments, detached from a steep hill side, always more or less angular and often of a large size, and 'slips' from ground where the rock is more sandy or argillaceous, and in which water is more or less the prime mover; the result being the descent, often very gradual, of a heterogeneous mass of mud and stones, whose power of progression is regulated partly by the slope over which it moves, and partly by the amount of fluidity of the ingredients composing it. Slips of rock fragments of the first class are, as a rule, sufficiently obviously connected with the source whence they are derived, and stand usually at a considerable angle, the slope varying, however, with the

size and character of the materials composing it. To no such origin as this can, I think, any of the barriers of the Kumaun lakes be attributed. 'Slips' of the second class, however, far more closely simulate a 'moraine,' but those possessed of most mobility, from the greater fluidity of their composition, are in the precise ratio of such fluidity least capable of withstanding removal by rain, or of bearing upon their surface craggy masses of rock such as I should term 'erratics,' and which, if not numerous, are at all events occasional and most significant constituents of some of the barriers. Mr. Ball mentions masses of rock 10 feet in diameter, as forming part of the barrier of Naini Tál, but this is an under-estimate, as some of the masses are double and treble that size. They have certainly not fallen from any neighbouring cliff, nor are the harsh comminuted rocks in the vicinity of the lake capable of forming a stiff mud on which they could have been transported, after the fashion of a 'moraine,' and the inference I therefore draw from them is, that they are really part of a 'moraine' and not brought into their present position by any of the ordinary modes of stream action.

Of Bhim Tál, Mr. Ball's account is hardly more satisfactory, in my opinion, than in the case of Naini, with the important exception, that he himself sees a serious objection to the application to it of the 'landslip' theory. Mr. Ball's words are: "Towards the southern end of the lake on the eastern side, there is a *boulder deposit*, which extends along the bank, up to a level of perhaps 10 feet above the water." Now, this "*boulder deposit*" is, according to my interpretation, part of a lateral moraine which descended from the peak above Sangri (6,320 feet), and in conjunction with that of the main glacier to the south, helped on the diminution of glacial conditions to block the direct exit of the valley to the south, thereby creating the lake. Mr. Ball goes on to add: "The most remarkable feature about it, however, is, that it is backed by no high range on the east, so that, if derived from a landslip, the materials must have come from the west, and of necessity *temporarily* filled up a *portion* of the bed of the lake." I do not see by what stretch of ingenuity Mr. Ball can defend the above sentence from the charge of very inadequately conveying the true state of the case. The course of the lake, so far as the "boulder deposit" extends, runs north and south. As there is no high ground to the east, the material, as Mr. Ball owns, if the boulder deposit originated in any way in a landslip, must have come from the west across the lake, but in so doing must have *obliterated* it altogether. To talk of this as temporarily filling up a portion of its bed is simply trifling with the intelligence of the reader. There being no scour, how does Mr. Ball suppose such a mass of materials to have been removed, and the bed of the lake cleared of its temporary obstruction?

Mr. Ball is further forced into the admission, very remarkable in his mouth, with reference to this "*boulder deposit*," that "its appearance suggests a moraine," though this is not very consistent with the appellation he bestows on it.

In considering, too, the question of the descent of a glacier down the valley from the north-west, Mr. Ball allows himself to be influenced by a difficulty which I confess I am far too dull to perceive the force of. So far as I can understand it, the difficulty, as it presents itself to him, is the possible or probable

prolongation of a spur of rock across the valley, which, I understand Mr. Ball to argue, would be a serious, not to say insurmountable, difficulty in his mind to the idea of a glacier ever having passed along it. To me it is nothing of the sort; for I can conceive no sort or description of spur blocking or constricting a valley which could offer any bar to the passage of a glacier: for the plain and simple reason, that wherever the stream which originally excavated the valley could go, a glacier could follow, and is, moreover, not so bound by hydrostatic laws as water is in its fluid state. Further into the matter than this I confess my inability to see.

Of Naukatchia Tál and Sáh Tál Mr. Ball expresses a confident opinion that their shape and surroundings preclude the idea of glacial agency being concerned in their formation, an opinion from which I profoundly dissent, especially with reference to the former lake, which I consider one of the most remarkable lakes in Kumaun, if not in the world, as I shall endeavour soon to show.

There is one remark in Mr. Ball's "*conclusions*" (p. 181 of his paper) which I cannot pass without comment, as I am painfully compelled to own I do not realise its cogency. The remark is couched in the following words:—

"There is one point geologically which links the three larger lakes together, and that is the occurrence of trap dykes in the vicinity of each." Is it reasonable to ask us to accept this dictum for argument? Is it not rather like clothing with scientific importance the crude geographical conceptions of honest Fluellen, touching the similarity between Monmouth and Macedon, as proved by their both commencing with the letter M? Why, too, the smaller adjoining lakes should be excluded from participation in the argument supposed to accrue from the presence of the dykes in the vicinity of their larger brethren, is not obvious. However, my colleague goes on to explain himself: "Now, I do not think it at all probable that the lakes are due to the original outburst of trap," an opinion in which I fully coincide, considering that such an idea is wholly beyond the bounds of the wildest possibility; but my colleague at once goes on to add: "But it seems not improbable that when the great upheaval and disturbance of the rocks of this area took place, the existence of comparatively rigid lines of trap may have been largely instrumental in determining the form which the surface assumed, and that on their flanks the soft shales, &c., may have been so much crushed and broken as to yield more easily to the subsequent operations of denudation, thus affording an abundant supply of materials for landslips, which ultimately served to close the valleys and form the lakes."

The two prominent ideas here presented are *firstly*, that "*rigid lines of trap have determined the form*" of the ground surrounding the lakes; and *secondly*, that the lakes are merely accumulations of water, dammed up by the "*abundant supply*" of soft shales washed off the flanks of the 'rigid lines of trap' in question. To this I can only say that the very existence of any such "rigid lines" is a matter of pure supposition on Mr. Ball's part, without the slightest evidence, so far as I am aware, in support thereof; and so far from the barriers which hold up the lakes

¹ The presence of an obstructing spur here has more weight against the glacial hypothesis than the absence of such spurs at Naini has in favour of it.—H. B. M.

being composed of 'soft shales,' it would be very hard to find such soft shales in any of the barriers I have examined. This is a plain issue. Are the barriers mainly composed of soft shales, or is that material mainly conspicuous in them by its absence?

Now, Mr. Ball himself tells us nothing about "soft shales" in the body of his paper. He therein describes the hills surrounding the lakes as consisting of "shales," "quartzites," "limestones," "argillaceous schists," "massive limestones," "highly indurated, but slightly calcareous mudstones," "white and purple quartzites," "greenstone," "trap," and even "granite and gneiss" (possibly) as members of the rock series of the district, but not a word of "soft shales" till we come to his 'conclusions,' wherein they are described as swathing his "rigid lines of trap," and by the "abundant supply of material" they have afforded, actually choking up the valleys, and thereby originating the lakes. In a word, Mr. Ball concludes that the Kumaun lakes have no connection whatever with former glaciers, but are due to landslips operating on soft shale, and the (to me) somewhat obscure influence of "rigid lines of trap." My own reason for regarding these lakes as glacial I shall now proceed to state.

The lakes of Kumaun may be divided into two groups,¹ *viz.*, those which lie in the direct course of an old glacier, and which may or may not occupy an ice-cut basin, and those formed by the occlusion of a valley by the projection across it of the material of a 'moraine.'

Class I embraces Bhim Tál, Malwa Tál, Naini Tál, the lowest of the Sath Tál group, and an unnamed lake above Khurpa Tál.

Class II embraces Naukatchia Tál, Khurpa Tál, Suria Tál, and the upper lakes of the Sath Tál group.

The origin of all is, however, identical, and putting aside all considerations of rock basins, which I have no immediate means of verifying, is due to the obstruction of local drainage, caused by the debris of old moraines on the retrocession of the glaciers at the termination of a glacial epoch.

The three principal lakes of Kumaun, Naini Tál, Bhim Tál, and Malwa Tál are situated in three separate, but parallel and adjacent drainage areas, the axis of each of which has a general south-east and north-west trend. The tract of country comprising this area is bounded on the north by so much of the hill range as extends from the vicinity of Gagan peak (7,855 feet) on the east to the Deoputhar peak (7,989 feet) on the west. Naini Tál lies a little below a horse-shoe shaped *coul de sac*, between the Deoputhar and Chini peaks, and is not only the largest (slightly) of the three, but the nearest to the culminating ridge, and whose basin may be said to display more obviously than the others the action of ice in its shape and character.

Its effluent waters give rise to the Balia river, which after a short south-easterly course, joins the Gola river a little below Ranibágh. Bhim Tál receives the drainage of the heights north of Bluwali, from which it bears exactly south-east, while 7 miles beyond it in the same direction is situated Naukatchia Tál

¹ For a map the reader is referred to Mr. Ball's paper (*l. c.*).

(the deepest of all the lakes according to Mr. Ball), the peculiar features of which I shall describe further on. Malwa Tál is simply an expansion of the Kalsa river, which with a south-easterly course drains the Gagan peak and adjoining heights, the drainage of all and the whole group of associated lakes being ultimately conveyed into the Gola river.

Bhim Tál and its neighbour Naukatchia Tál are separated from Malwa Tál by a lofty range with peaks from 6,413 to 6,320 in height; whilst from Naini Tál, Sáth Tál, and the lakes which drain into the Balia river, they are separated by a somewhat lower range of only 5,820 feet in height.

The most remarkable lakes are Bhim Tál and Naukatchia Tál, and their peculiar relation to each other renders it desirable to consider them together.

BHIM TÁL & NAUKATCHIA TÁL.

Even the new 1-inch maps of the country give no adequate idea of the peculiar features of the drainage of these two lakes. For example, the villages of Dhansila and Padani are situated on opposite sides of the stream which conveys away the surplus waters of Bhim Tál, a fact that it would be impossible to surmise from the map; indeed so far as I can make out, no escape whatever for the surplus waters of Bhim Tál is shown on the 1-inch map. One thing is apparent on the ground, and has been noticed by Mr. Ball, that the present drainage of Bhim Tál does not appear to be in the same direction as that it originally pursued, and I would extend the remark to Naukatchia Tál as well. Bhim Tál and Naukatchia Tál both stand in the same general south-east line, but the actual drainage line between them is slightly deflected on one side by the ridge on which Dhansila stands. At present the surplus waters of Bhim Tál make their escape about the centre of the lake on its east side, flowing under Dhansila (that is, to the north-east of it) with a prevailing south-east course as already stated. But there can be very little doubt that the original exit of the waters of the main valley, of which a submerged section now constitutes the present lake, was directly to the south and to the west of Dhansila instead of to the north-east of that village. My explanation of course is, that the escape waters found a readier passage through the lateral moraine skirting the east bank of the lake, than at the original point of discharge to the south, through and across not only the accumulated materials of the principal moraine, but the added accumulations of the eastern or lateral moraine (Mr. Ball's '*boulder bed*') and a similar accession from the western slopes, which all helped to jam the throat of the gorge to the south. Be this as it may, the surplus waters now find their way beneath Dhansila, flowing to the south-east, till at a little less than halfway to Naukatchia Tál they are met by the surplus waters of that lake, flowing in an exactly opposite direction to the north-west. The hydrographical situation is peculiar, not to say embarrassing, but the result is, that the united waters of both lakes are deflected at almost a right angle to their joint courses, and flow to the south-west, through a narrow gorge in the trap ridge on which Dhansila stands, into the Gola river. Resuming our course from the above junction, in a south-eastern direction, and which would be called *down* the valley, but for the anomaly of the

stream flowing towards us, we at last reach Naukatchia Tál. Facing still to the south-east, we have on our left the lofty range separating the valley from Malwa Tál and on our right the low range on which Dhansila and Sirori are built. In front of us is Naukatchia Tál, and beyond Naukatchia Tál the valley comes to an abrupt end, and a very remarkable one.

As in the case of Bhim Tál, so in the present instance the original and natural course for the surplus waters of Naukatchia Tál would seem to be to the south straight into the Gola river, a distance of but a little over 6 miles, instead of which they reach the Gola by a circuitous course of 16 miles, the first 4 of which seem a reversal, as far as direction goes, of the original drainage of the valley. The main obstruction, looking across the lake in a south-east direction, is a low hill, somewhat centrally situated, and which is evidently composed of rock *in situ*. On the left this hill is united with the Mahrageon range by sloping ground, much masked by detritus from the heights above, along which the road from Bhim Tál to Malwa Tál is carried. Here, too, I think, there is little doubt that the valley is closed to a higher level than the lake, by rock *in situ*. On the right hand side, however, of the central hill, such does not appear to be the case, and on this side would seem to be the original and natural outlet of the lake, or of the valley prior to the conversion of part of it into a lake. The only obstacle here interposed between the waters of the lake and a precipitous valley leading straight down into the Gola river, is what I may designate as a causeway, wherein I could detect no rock *in situ*, and which resembles nothing more than a railway embankment connecting the central hill with the opposite or south-west side of the valley. This bank which might be (not that I wish to infer that it is of artificial origin) is not 50 feet broad at the top and forms the watershed between Naukatchia Tál at its immediate foot on one side and a sheer descent into the Gola river on the other; it has no appearance of a 'landslip' and any slip from the central hill would take place rather to the south-east which is its precipitous side than to the south-west where this bank connects it with the high ground opposite. The waters of the lake actually rest against this bank, without any intermediate catchment area in that quarter, and yet the lake is a deep one. If, then, this bank is not a 'landslip,' there seems no resource left but to regard it as a moraine, which crossed the valley at right angles from the heights behind Mahrageon, thereby creating the lake by obstructing the drainage. Every collateral consideration favours this view. In the first place, we must remember that there is every reason to suppose (as remarked by Mr. Ball) that the original course of the stream (and in my view, of the glacier subsequently) through Bhim Tál was out and through its extreme southern end. Then the ground between Bhim Tál and Naukatchia Tál is so open and level as to suggest the possibility of its having been once continuously covered by a lake embracing in its limits both the existing lakes, and that the spot below Dhansila, where the escape waters from both lakes meet, was originally a low water-parting between them. On the supposition that the lakes were once united, this reversal of conditions is easily understood. The lakes being both simultaneously and similarly blocked at their natural outlet to the south, continued to rise and

spread, till their united waters discovered the weakest part of the barriers enclosing them. This was at Dhansila, which at once became the point of discharge for their joint waters, the constant cutting action of which has resulted in the features the ground now displays. Whilst then the glacier of Bhim Tál was descending west of Dhansila, the glaciers descending from the heights between Mahragaon (behind Naukatchia Tál) and Padani, were pushing straight across the ground immediately below them, with the result that the Padani glacier cut through the trap ridge, and initiated the channel by which the waters of both lakes *now* escape, whilst the Mahragaon¹ glacier pursued a parallel course west of Sitalahat, its 'moraines' serving to impound the drainage between Padani and Mahragaon, thereby creating Naukatchia Tál.

The point of supreme interest of course is, why a circuitous exit across a hard trap ridge should have been selected by the waters of both lakes in preference to a more direct and undeniably natural course across the apparently weaker obstacle of a landslip or 'boulder bed.' As regards a boulder bed initiating a lake, I may observe that every Himalayan gorge is full of boulders, but in no instance do they give rise to lakes. A flood may throw a bar of them across the channel, but the next flood makes a clean sweep of the obstruction. Of course the 'boulder bed' which could be presumed to have given rise to the lake could not have itself originated therein, and besides the Kumaun lakes, from their limited dimensions and sheltered situation, do not produce *boulders*, being very different from those grand Italian lakes

"Tu Lari maxime, tuque

Fluctibus et fremitu assurgens, Benace, marino,"

and in the deepest of them, Naukatchia Tál, the sides may be seen dipping down at a steep angle and composed of angular fragments evidently never disturbed by wave motion. The result of my own examination of the point of exit of the joint waters below Dhansila was very instructive. At Dhansila there is no doubt of the ridge whereon it stands being composed of rock *in situ*, but across the gorge through which the stream passes, that is, exactly south-east of Dhansila, I could detect no rock *in situ*. The entire ground is covered with loose subangular masses of hard trap, up to even 100 feet girth, but no rock *in situ* could I detect after a careful search. There are some rocks of course which from their composition decompose so freely at the surface, that it is not easy to find a clean natural section or exposure of them; but such is not the character of the harsh intractable trap of Malwa Tál and the neighbourhood, such as formed the bulk of all the fragments here strewed about. To me the conclusion was overwhelming, that I was on the 'moraine' of an old glacier which had wound past Dhansila, and along whose channel the escape waters of the two lakes had made their passage.

The ice work of the old glacier, sawing its way across the obstructive ridge at Dhansila, renders it easy to understand how the waters of both lakes, on their natural point of discharge being blocked, came to select this point as the

¹ That above Naukatchia Tál, not the village of the same name, north of Bhim Tál.

easiest for their new course, and such I believe to be the true explanation of an otherwise puzzling phenomenon.

The only thing to be said against it is, that it must stand or fall with the glacial hypothesis of the origin of the lakes.

NAINI TÁL.

My notes on this lake need only be brief, as I have already noticed the chief points wherein I differ from Mr. Ball respecting it. The most important remark I have to make is regarding what remains of the old Naini moraine. Of course I regard the barrier as virtually composed of old moraine materials, but immediately below the 'barrier' the 'moraine' has been engulfed in the steep gorge, down which the escape waters of the lake precipitate themselves in their course to the Balia river. If, however, leaving the 'outfall' of the lake, we go along the cart-road, till we come in sight of the Brewery (*Sharáb-batti* of the 1-inch map) and direct our eyes beyond it, we can see a little to the left of it (and of course below it) a small hill. This hill, in my opinion, constitutes one of the most prominent 'hummocks' of the old Naini 'moraine,' there still preserved intact, and *in situ*. The stream which below the 'outfall' of the lake has cut away and engulfed the old 'moraine' in the chasm worn by its waters, has lower down found an easier channel to the westward, and hence for some distance above and below Suria Tál, the old Naini 'moraine' still remains intact. Suria Tál is indeed merely a pool formed by the local drainage being shut up by the 'moraine' sweeping past to the south-west. The village of Gitia (which is not marked on the map, but lies west of Suria Tál) stands on the 'moraine,' and below it spreads a highly irregular, 'hummocky' surface, freckled over with monstrous angular blocks of limestone, derived from the Naini basin and constituting the actual 'body and bones' of the old 'moraine.' At least this is my idea. I confess I *did* see a difficulty once, not sufficient to outweigh the evidence afforded by the physical character of the ground, but still a difficulty, and that was, that the section displayed on the river abreast of this 'moraine' was one of ordinary river boulder gravel; very coarse no doubt, but *not* distinctly marked by the presence in it of the huge erratic masses which encumbered the surface a short distance off. I did not then know what my last season's work has placed beyond all question, that the 'moraines,' to whose action I attribute the formation of the Kumaun lakes, are far newer than the old gravels filling the valleys, and on which old gravels they may occasionally be seen to rest. I shall not here enter further on this important discovery, beyond saying that it at once disposes of the difficulty I once felt in the fact of the huge 'erratics' embedded in the 'moraines' (as I regard them) not being seen in the old gravels; but the full discussion of this question must be reserved for another paper.

MALWA TÁL.

This lake, if the form of its basin is less suggestive of a glacier than is the case with either Naini Tál or Bhim Tál, is one which it is, on the other hand, more difficult to regard as due to a landslip than almost any lake in Kumaun.

It lies in the direct course of what in the rains must be a considerable river, and though the sides of the valley are steep, they do not so materially differ in this or any other respect from other gorges in the hills as to afford an adequate explanation why a 'slip' from them of loose materials should produce a result which we cannot trace elsewhere where similar physical features prevail. I have already dwelt on the point that banks of shingle (and fallen detritus from the sides of the valley would share the same fate) do not in Himalayan streams, be they large or small, give rise to permanent lakes, and it is therefore difficult to understand how Malwa Tál comes to occupy the position it does, save on the supposition that it lies in a basin cut out of the rock by a glacier. On the descent to Malwa Tál by the road from Bhim Tál some very hard and massive trap is seen, and it appears as though a band of this rock crosses the valley just below the lake. If this supposition is correct, and if a glacier ever did descend the valley, the natural result would be the formation of a rock basin in the position now occupied by the lake, owing to the more energetic excavation effected by the glacier in the comparatively softer rocks above than on the hard band of rocks which may be considered as forming the lake sill at its point of discharge. It is true Mr. Ball declares no rock *in situ* is there visible, but without admitting that this fact has been satisfactorily established, or can be by a mere superficial examination, I would suggest that, considering the steepness of the sides of the valley, we may not unnaturally expect to find the bottom covered with a considerable amount of loose debris, quite sufficient to conceal any exposure of rock at the surface.

From different aspects, therefore, do the three chief lakes of Kumaun—Malwa Tál on the one hand and Naini Tál and Bhim Tál on the other—give strong countenance to the idea that they one and all originate from glacial agency.

KHURPA TÁL.

This lake, which every traveller to Naini Tál from Káladungi must have remarked after turning the corner of the spur which descends from Deoputhar peak, is a little cocked-hat sort of depression, immediately below the road, encircled by rather steep sides, and with no visible outlet. Its natural outlet should be at its northern end, and percolation through a barrier of loose stony materials in that quarter no doubt suffices to carry off its surplus waters. But what is the nature of this barrier? The choice avowedly lies between Mr. Ball's theory of lake formation in these hills by "landslips" and mine by "moraines." It is to be regretted that Mr. Ball does not seem to have examined this lake, since it is one which, in my opinion, places the "landslip" theory entirely 'out of court.' In the case of Khurpa Tál the only direction whence the materials of the barrier almost encircling it could have been derived by a slip is from the abrupt flanks of the Deoputhar spur to the north-west. But the lake itself nestles at the foot of the spur and occupies the position of the hypotenuse of the slope which such a fall of materials would have created, and I need hardly point out, that no forces of nature could create a lake in such a position, that is, on the slope or hypotenuse of a mass of fallen rock. Regarding the 'barrier,' however, as a 'moraine,' no difficulty is

encountered. The glacier which brought down the 'moraine' in question, descended in a southerly direction from the peak of 7,989 feet, standing at the head of the Naini basin, and from the opposite side from that whence the Naini glacier itself descended. The valley traversed by this glacier (and along which the road to Naini from Káladungi winds) is towards its head blocked, or encumbered with a confused mass of angular blocks, which in part at least represents the old 'moraine,' though the Deoputhar ridge and the Iarputhar ridge on the opposite side are both so steep that avalanches and landslips may have largely added to its original mass. The progressive movement, however, of the bulk of this mass can, I think, only have been effected by ice, as the blocks composing it are so large and angular, the slope so high, and the surface so incapable of generating a large stream, from the water sinking engulfed in the interstices between the blocks, that fluviate action is impossible. Some halfway down the valley, this mass, which I designate a moraine, terminates in a steep bluff, precisely resembling on a large scale an unfinished railway embankment, and below this lies the unnamed lake (or lakes, for the map shows two), across the outlet sluice of which the road is carried towards Naini after passing Khurpa Tál. Below this outlet sluice the valley rapidly falls (the moraine being here probably engulfed in precisely the same fashion as is the case below the Naini outfall), till past the old iron furnace, which stands nearly in its path, when the usual and characteristic components of a moraine are met with in profusion all round the spot on which the large bungalow, beyond the furnace, is built; and it is this moraine which intercepts a small portion of the drainage from the Deoputhar spur, and thereby gives rise to the little cocked-hat, dignified by the name of Khurpa Tál, but the interest and value of which as bearing on the origin of the Kumaun lakes is in inverse ratio to its tiny dimensions. There is one point, perhaps, which calls for notice in connection with the above small unnamed lakes, and that is, that they lie directly in the path as it were of the above 'moraine' (as I regard it, which I have described as terminating in a steep bluff) and occupy an intermediate space, comparatively free from large blocks between the moraine above them, and the similar heterogenous assemblage of rocky materials, met with lower down around Khurpa Tál. The reason is, in my opinion, not far to seek if we reflect on the conditions under which such a 'moraine' was formed in so rocky and precipitous a gorge as that east of the Deoputhar ridge. A 'moraine' is made up in varying proportions, according to the character of the rocks, of materials projected on to it in a more or less irregular fashion from both sides of the gorge or valley down which it is slowly progressing, and comparatively bald places may be left on it, wherein few or no large blocks may be found. The same aspect of the surface may also be induced by the filling up of irregular dips therein by ordinary rainwash, the silting up of all interstices between the larger blocks being the probable cause of the small unnamed lakes in question.

SÁTH TÁL.

The group of Sáth Tál, or seven lakes, as the name implies, is represented on the map by but three—namely, a small one to the north, a large one to the south,

evidently compounded of two or more contiguous basins united, and a minute lake to the west. As in the case of Bhim Tál and Naukatchia Tál the drainage of these lakes can only be indistinctly made out from the map. The small lake to the west is the lowest, and the drainage from the other lakes is passed through it. It is mainly remarkable, as affording a complete disproof of the notion of any overpowering rush of water, being the agent whereby the large blocks seen in the barrier of the large lake just above it were brought down to their present position, as any such rush of water so laden with stones and mud must have simply obliterated this little hollow, as easily as a man's thumb wipes out a spot of ink. The barrier below it is of large rough stones, fallen mainly from the hills adjoining it, which are so permeable that they do not allow its waters to ever stand for long at a high level; but although thus permeable to clear, or moderately turbid water, anything like a moving flood of mud capable of bringing down enormous masses of rock, must have filled up the lake flush with its barrier, and then passed onwards down the gorge. But this obliteration of the tiny basin has not occurred, therefore no such floods can have ever passed over it.

The uppermost lake to the north is a little cocked-hat of a lake with steep sides of loose materials, and without visible outlet, in this respect resembling Khurpa Tál. Its surplus waters, however, find an exit by percolation through the barrier (moraine) separating it from the larger lake, whose surplus waters they join below the barrier. The larger lake is created by the obstruction caused by the above barrier. This barrier is a huge bank of earth and stones, some of the embedded blocks of rocks measuring 30 or 40 feet in girth. This mass of materials, which I cannot but regard as a 'moraine,' has crept down from almost due north, till arrested by the hill whereon Siloti stands. The impounded drainage from the eastward has consequently gathered into the form of a lake of very irregular shape, the escape waters from which have scoured a passage for themselves, between the termination of the moraine and the mountain side, whereon it abuts, and whereby it became arrested and deflected to the west from its north and south course. It is an objection in the mind of some, who are opposed to the idea of ice action, that the ultimate source or head of this moraine is not quite a mile off. This, so far from being a valid obstacle to the view adopted by me, is probably, as I shall endeavour soon to show, the main cause of the very existence now of the lake, and moreover such objectors should reflect that if a limited catchment area is opposed to the genesis of a large moraine, *a fortiori* is it incapable of giving birth to a stream adequate to transporting such blocks as help to form the barrier in question.

CONCLUDING REMARKS.

Having attempted in the previous pages to establish a case in favour of the idea that glaciers have been the proximate agents in the formation of the lakes of Kumaun, if not by the actual excavation of a rock basin in all cases, at least by the obstruction, caused on their retrocession, by the large accumulations of 'moraine' matter abandoned in their wake, I would offer a few words touching some objections which may be urged against my views.

It will not be contended, I think, and certainly not by myself, that the Kumaun district is distinguished *cæteris paribus*, as regards climate or as regards any occult orographical features, from any similar and corresponding area of the Himalayan region in general. If, then, the Kumaun lakes are due to glaciers, and if (as I hold) similar glacial conditions extended far and wide beyond the limits of Kumaun, how comes it, it may not impertinently be asked, that the entire Himalayan region is not similarly dotted over with lakes, large and small, as in a part of Kumaun? How comes a cause, exercised over so wide an area, to be attested by results confined within such narrow limits? For my part I frankly accept the first deduction, and believe that the entire Himalayan region was once dotted over with lakes, originating in the same causes and in the same manner as those of Kumaun, but from the physical or petrological character of the rocks in the vicinage of the Kumaun lakes they have remained (or many of them), whilst the great majority of the lakes of contemporary origin over the entire Himalayan region have disappeared under the operation of ordinary denudational forces. Malwa Tál illustrates, in my opinion, the process in question. It is one of the largest lakes in Kumaun, and possesses out of all comparison the largest catchment. Under any circumstances of origin, we might therefore expect a barrier of corresponding dimensions. But 'barrier' there is none save the artificial sluice wall. True, one may potter about the outfall without detecting rock *in situ*, but there is nothing analogous to the mole-like mass which constitutes the 'barriers' of the other lakes. Doubtless the reason is, the flood waters of its large catchment area have swept the whole away, and the lake owes its continued existence to the fact of its having been endowed with not only a barrier, but a true rock basin likewise. The one has disappeared, the other remains. This, it may be alleged, is mere supposition, but it is not unwarranted, I think, by the circumstances, for other *raison d'être* for this lake save a rock basin, I can imagine none.

The hard limestones, traps, and trap-like schists, of this part of Kumaun readily break up into a confused heap of fragments of all sizes, and the fragments heaped together (as I argue in the shape of moraines) form an obstacle, practically, in most cases, unassailable by the slender supply of water passed over them. In such a case as Malwa Tál with its large catchment area, the 'barrier' does go. In Naini Tál and perhaps other instances, the said 'barrier' becomes attacked in places, and undercut and partially engulfed in the chasm formed by the stream, which is wholly powerless to remove it in any more direct fashion, whilst in the smaller lakes, with no catchment area to speak of, beyond their sloping sides, we see the pent up waters finding their way out by percolation, through the loose materials which surround them.

I doubt not moreover that an additional argument and illustration of the view here set forth will be found when the lakes high up on the frontier of Northern Hazára come to be examined. These, too, clearly have very small catchment areas, to which, as in Kumaun, their survival is probably due, but political considerations at present stand in the way of a European spending much time in the neighbourhood of the independent hill tribes in that quarter.

ON THE DISCOVERY OF A CELT OF PALÆOLITHIC TYPE IN THE PUNJAB, by W. THEOBALD, *Geological Survey of India.*

The celt, to which this notice refers, is interesting, as being the first specimen of these articles yet discovered in the Punjab, so far as I am aware. 'Chips' and 'scrapers,' and remarkably fine 'cores' of chert, have been found in Sind, but no larger implements. The present celt is composed of a pale homogenous limestone, probably of nummulitic age, and presents a surface much corroded by exposure to the atmosphere, the stone of which it is composed being evidently of a character to suffer materially from such exposure. The shape, however, of the article and the peculiar sinuous edge, the result of chipping from alternate sides, leaves no doubt as to its artificial character. It is, however, so rudely formed, that many similar specimens might escape observation, save to the practised eye of one familiar with such objects, and it is hoped that the present notice of this 'find' may result in the discovery of other specimens. It was picked up by myself on February 21st, 1879, on the surface of the ground, exactly opposite the village of Shodipur, on the Indus, 25 miles as the crow flies in a south-west direction below Attock. On showing the specimen to Kishen Singh, of the Geological Survey, he informed me he had once picked up a similar article near Rhotas, but being in doubt as to its character, had thrown it away again. This was unfortunate, but I mention the circumstance to direct the attention of future observers to the probable occurrence of these articles in other parts of the Punjab.

PALÆONTOLOGICAL NOTES FROM THE KARHARBARI AND SOUTH REWAH COAL-FIELDS, by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

At end of last March and beginning of April, I had an opportunity of re-visiting the Karharbári coal-field, and, thanks to the kindness of Mr. W. G. Olpherts, C.E., F.G.S., the present manager of the East Indian Railway Company's Collieries, and to the assistance of Mr. N. Miller, Inspector at Passerabha, I could collect further information regarding the comparison of the seams and the flora at the various places, supplementary to the views advanced in my *Talchir-Karharbári flora*.¹ I had the good fortune to collect numerous fossils from the second seam, from which none were hitherto known. As will be seen hereafter, this flora differs to a certain extent from that of the lower seam, and it would therefore appear that, although the parting between the second and the bottom seam is only thin, they have to be considered as distinct. I also obtained specimens from the other seams, so it will be well to say a few words about each of them. I shall do so in ascending order.

1. *No. 1 seam—bottom seam.*

Fossils from this coal seam are enumerated in my flora from eight places,

¹ *Pal. Indica*, Ser. XII, pt. 1, 1879.

three in the Serampur area,¹ and five in the Karharbári area² of the field. They come out of the shales in the roof of the seam.

It is this seam which has the greatest number of the peculiar fossils, and is most closely connected with the Talchir group. Of the common Damuda fossils we find *Glossopteris*, only rarely, and of *Vertebraria*, only two very small fragments were met with at one locality, No. 5D shaft, Passerabhhia.

During my recent visit to the field, I did not collect many fossils from the bottom seam, but I happened to discover, amongst other rock specimens lying at the manager's office at Giridi, two nice specimens of fossils which Mr. Olpherts was kind enough to present to our Museum.

One of the specimens is from the bottom seam (No. 5D shaft) at Passerabhhia (Karharbári), the other from the same seam (No. 11A shaft) at Buriadi (Serampur).

I also secured other duplicate fossils from these two shafts.

There are amongst them—

Neuropteris valida, Fstm., from both shafts.

Nöggerathiopsis hislopi, Fstm., also from both shafts.

Of this latter the two specimens presented by Mr. Olpherts are very large leaves, the largest we at present know from India; they will be figured in a supplemental fasciculus to the Talchir-Karharbári flora of the Palæontologia Indica; the specimen from Buriadi is almost complete, the basal portion only being broken off, while the apical portion is perfect. The Passerabhhia specimen is although almost as large as the former, not so complete, a good deal of the apical portion being wanting; it shows, however, quite well the characters of the species, and must originally have been of a very large size.

The sections of these two shafts, showing the position of the fossiliferous shale, have been given in my Talchir-Karharbári flora,³ to which I now refer.

I have picked up a few fossils at a new locality, No. 5 shaft, Jogitand, which also works the bottom seam. I give the section in descending order⁴:—

No. 5 shaft, Jogitand.

Soil	1'
Sandy brown clay	38'
Sandstone	18'
Strong dark shale	5' 9"
Sandstone	47' 3"
Strong dark shale with bands of coal (includes representative of 2nd seam)	5' 3" [Fossils from the base of this band.
No. 1 seam: coal	12'
Total	127' 3"

¹ Buriadi (11A); Chunka (Nos. 16 and 16G shafts).

² Passerabhhia (Nos. 5D and 5G shafts); Mathadi (No. 1); Jogitand (No. 2) Domanighât.

³ Pal. Indica, Ser. XII, pt. 1, pp. 36, 39.

⁴ This and the two following sections were kindly supplied by Mr. W. G. Olpherts.

The fossils found represent, however, one species only :—

Nöggerathiopsis hislopi, Fstm.

The position of the fossiliferous band is the same as in No. 2 shaft Jogitand (*l. c.* pp. 42, 43); three species were named from this latter shaft, which are those of the bottom seam elsewhere.

We now know, therefore, fossils from the bottom seam from the following places :—

Karharbári area.	Passerabhia, shafts No. 5D, No. 5G; Máthadi, shaft No. 1; Jogitand, shafts No. 2, No. 5; Domahni ghat.
Serampur area.	Buriadi, shaft No. 11A; Chunka, shafts No. 16 and No. 16G.

The thicknesses of the bottom seam at the respective places are—

11' (including 3' partings), 11' (including 3' partings), 13', 8', 12', 9', 14', 9', 12' 6".

The coal belongs to the lowest hitherto known in India, and owes perhaps to this circumstance its superior quality.

No. 2 seam.

Already in my Flora of the Talchir-Karharbári beds (*l. c.* pp. 39, 40) when quoting the sections of shafts Nos. 5D and 5G (Passerabhia), I indicated the existence of a second seam above the bottom seam, separated from this latter at both places by a 2' 6" parting of laminated sandstones and shales, in which the fossils of the bottom seam were found; the coal measured 7' 2" and 7' respectively; both seams are worked together at these places.

At Jogitand this second seam is much thinner, being 2' 6" in No. 2 shaft, and being represented by dark shale in No. 5; the parting of black shale at No. 2 is 2' 5" thick.

At Máthadi the second seam is represented by only very thin bands of coal, separated by 6' 7" sandstone and shale from the bottom seam. At Domahni ghât are two outcrops of coal, one of which is the second seam; in the Serampur area there is also another seam close above the bottom seam which measures at Buriadi (shaft 11A) 2' 6", at Chunka (shaft 16) 7' 6", and (shaft 16 G) 6', being separated from the bottom seam by 3' 3", 12' 6", and 6' 6" sandstone and shale partings, from which latter the fossils were procured, by which the lower seam here was correlated with the same in the Karharbári area.

No fossils were up till lately known from the layers above the second seam, the reason of which certainly lies in the overlying rock at the places mentioned consisting of sandstone only, which is very badly adapted for preservation of plants.

During my recent visit, however, I just came in time to collect fossils at two pits which work the second seam separately, the bottom seam being not reached yet, or not cut through, so that I am now able, for the first time, to introduce fossils from the second seam; the two shafts are in the Karharbári area, at Passerabhia, and their numbers are, No. 24 (29 new) and No. 40 (33

new). I shall name the fossils from each separately, quoting also the sections of the shafts to show the position of the fossiliferous band.

No. 24 (29 new) shaft, *Passerabhia*.

Section.		
	Soil and brickwork	31' 4"
	Sandstone	11' 1"
	Coal	1' 9"
	Sandstone	2' 4"
	Coal	2' 8"
	Sandstone	15' 6"
	Coal	1'
	Sandstone	7' 8"
	Shale	7" Fossils found in this band.
2ND SEAM .	Coal	1' 3"
	Carbonaceous shale	2"
	Coal	9"
	Soft, laminated bright coal	2"
	Coal	3' 1"
	Carbonaceous shale	5"
	Burnt coal (by trap)	1' 7"
	Bottom seam not reached.	
TOTAL		184' 7"

The thickness of the seam is therefore 7' 8", with 7" partings of shale, which corresponds well with the thickness of the second seam in the sections of shafts Nos. 5D and 5G¹ (*Passerabhia*).

The fossiliferous band in the present shaft is the 7" shale above the coal.

It is very dark grey, very close, shale crowded with fossil leaves, which partly are in so close layers that it is difficult to get an entire leaf.

The fossils are—

Glossopteris communis, Fstm. Very numerous.

Gangamopteris cyclopteroides, Fstm.

Nöggerathiopsis hislopi, Fstm. Rare.

Shaft No. 40 (33 new), *Passerabhia*.²

Section.		
3RD SEAM .	Soil and brickwork	9' 6"
	Sandstone	18' 3"
	Coal	7' 11"
	Sandstone	19' 4"
	Shale	1' 2"
	Sandstone	82' 1"
Carried over		138' 3"

¹ Pal. Indica, Ser. XII, pt. 1, 1879, pp. 39, 40.

² This section is also otherwise of interest, showing the position of all the three seams of this area.

		Brought forward	. . . 138' 3"
	Dark sandstone . . . . .	. . . . .	4' 11"
	Sandstone . . . . .	. . . . .	11' 10"
	Stony coal . . . . .	. . . . .	2' 3"
	Sandstone . . . . .	. . . . .	10' 9'
	Stony coal . . . . .	. . . . .	6"
	Sandstone . . . . .	. . . . .	17' 1"
	Shale (fossiliferous) . . . . .	. . . . .	10"
2ND SEAM	{ Coal . . . . .	. . . . .	1' 10"
	{ Carbonaceous shale . . . . .	. . . . .	2"
	{ Coal . . . . .	. . . . .	1' 1"
	{ Burnt Coal . . . . .	. . . . .	4'
	{ Trap . . . . .	. . . . .	1"
	{ Charred Coal . . . . .	. . . . .	1' 1"
	{ Sandstone . . . . .	. . . . .	11"
	{ Carbonaceous shale . . . . .	. . . . .	2' 7"
	Sandstone . . . . .	. . . . .	10"
	Shale . . . . .	. . . . .	4"
1ST SEAM	Bottom seam, stony and burnt (Seam not cut through)	. . . . .	3'
TOTAL			202' 4"

The fossils at this locality were more various, and are preserved partly in a dark fine, grained shale, and partly in a more sandy rock. They are—

Schizoneura? (probably? *gondwanensis*)—two specimens, rather badly preserved, but showing apparently an arrangement of leaflets like in *Schizoneura*, with dissolved sheaths.

Equisetaceous stalks. These are very numerous, and all of the same kind, *i.e.*, very broadly ribbed, ribs and furrows in juxta-position. They are presumably the stalks and stems of the same plant, to which the above-mentioned leaved specimens belong, probably *Schizoneura*.

Vertebraria indica, Royle.—Several specimens of the real Damuda form; also branched specimens.

Gangamopteris cyclopteroides, Fstm.—The common form.

Glossopteris communis, Fstm.—Several specimens.

Glossopteris sp.—A more oval leaf, with comparatively a very long stalk.

Nöggerathiopsis hislopi, Fstm.—Several specimens, both in the dark shale and in the more sandy variety.

Seeds.—Small, slightly winged, belonging perhaps to *Nöggerathiopsis*.

Taking now these fossils and those from No. 24 into close consideration, we find that although the second seam is separated from the bottom seam by a comparatively thin band only, yet the flora has a slightly different character. *Vertebraria* becomes more numerous, and *Glossopteris*, although representing only

one or two species, occurs in greater numbers. Two not very favourably preserved specimens appear to represent *Schizoneura gondwanensis*, Fstm.

No fossils were found as yet from the seam above the bottom seam in the Serampur area, but the correlation of the second seam in the Karharbári area, with that in the Serampur area, is apparently correct, the bottom seams in both areas being the same.

The 3rd seam, Passerabhia.

There is not much new to be reported from the 3rd seam area (*l. c.* p. 40). I have obtained a few specimens from shaft No. 17 B¹ which represent a species already known from this place, *viz.*, *Nöggerathiopsis hislopi*, Bunb.; some specimens indicating very large leaves.

From shaft No. 17 C I have obtained one specimen which contains three forms new for this place and therefore for the 3rd seam.

Gangamopteris comp. *angustifolia*, McCoy.—One leaf.

Winged seeds.—Of the same kind as that one figured by me from Buriadi² and known also from Mohpáni. Similar seeds, but smaller, are also known from the Damuda and Panchet division. I take them to represent the genus *Samaropsis* (comp. *parvulz*, Heer and Schmalhausen).

Seed.—Another large seed also was found. Of this I can form no idea at present, but I shall figure it with all the other new forms in a supplement to the Talchir-Karharbári flora.

This third seam appears to be developed in the northern portion of the Karharbári area only.

No. 4 seam, the "hill-seam."

In my already-mentioned paper I also mentioned the seams on the Komaljore and Bhuddua hills, classing them as a 4th seam, and judging from some fossils found on the Komaljore (Lumki) hill, and from the very much higher position of the seam, I represented them as belonging most probably to the Damuda division. No fossils were known from the Bhuddua hill. This time, however, I collected some fragments from above the coal; they are *Glossopteris*; they are of course at present quite insufficient for any conclusive decision, but I think there are stratigraphical points enough which, in combination with the fossils from the Lumki hill, show that it is an independent seam.

Bali hill in the western portion of the field is another place where this "hill seam" is represented. I have not yet examined this locality, but intend to do so on the first opportunity, as it is probable that more fossils may be found there, from which the horizon may be better fixed.

¹ The sections of this shaft, as well as of the other one, No. 17 C, are described in my Talchir-Karharbári flora, *l. c.* p. 40-42, where I also named the fossils.

² Ibidem, Plate XXIV, fig. 5.

The relations of the various seams may be shown in the following tabular list:—

DIVISION.	Number of seam.	Western portion.	Karharbāri portion.	Serampur portion.	FOSSILS.
Damuda Division.	1th	"Hill seam" on Bali Hill.	"Hill seam" on Bhuddua; fragments of fossils (<i>Glossopteris</i> .)	"Hill seam" on Lumki Hill; a few fossils.	Named in my Talchir Karharbāri Flora, p. 44. <i>Sphenopteris polymorpha</i> , Fstm. worthy of notice. Barākars.
		P	About 200' sandstone down to the next seam.	?	
Talchir Division.	3rd	The outcrop of seams at 'Purdaha, Lepadib and Ratighat, in Khakoo River.	3rd Seam at Passerabha (No. 17B and 17C shafts.		Named l c., same page. Besides: <i>Gangamopteris angustifolia</i> , McCoy. <i>Samaropsis</i> comp. <i>parvula</i> Heer, seed. Karharbāri beds.
	2nd		2nd seam at Passerabha (No. 24 and 10 shafts) Mādhadi, Jogitand and Domahni. Fossils known from the first place.	2nd seam at Buriadi and Chunka.	Identified now for the first time:— <i>Schizoneura ? gondwanensis</i> Fstm.; <i>Equisetaceans</i> stems; <i>Vertebraria indica</i> , Royle; <i>Gangamopteris cyclopteroides</i> , Fstm. <i>Glossopteris communis</i> , Fstm.; (rather numerous) <i>Glossopteris</i> another sp., <i>Neggerathiopsis hislop</i> , Hump. sp. (Feistm.); seeds. Karharbāri beds.
	1st		Bottom seam at Passerabha (No. 5D, No. 53) Mādhadi (No. 1) Jogitand (No. 2 and 5), Domahni.	Bottom seam at Buriadi (No. 11A), and Chunka (No. 16 and 16G).	Named in the above work, p. 44. Of interest, the two large leaves of <i>Neggerathiopsis</i> , Fstm. procured this time. Karharbāri beds.

Talchir Group.

PALÆONTOLOGICAL NOTES FROM THE SOUTH REWAH COAL-FIELD.

From this extensive coal-field there were hitherto comparatively very few fossils known. Those we possessed were plants only, and belong to two collections; of the one made in 1861 by Mr. J. G. Medlicott the specimens were labeled "South Rewah" and "Sohāgpur;" the former designation corresponds with what now will be distinguished as the Gopat river area, while the latter name will be retained.

Another collection, sent by Mr. C. A. Hacket, 1872, contains a few fossil

plants from the Son river, west of Garara, a place that is also represented in the collections received recently from Mr. Hughes.

From those fossils and their equivalents elsewhere I had judged that they represent the Raniganj (Kámthi) group, an opinion which the subsequent collections have confirmed.

Since October last a regular survey of this field was begun by Mr. Hughes, who has already been fortunate enough to procure a large number of interesting fossils, both vegetable and animal, which are of great importance for fixing the horizon of the beds.

Mr. Hughes has sent two collections; the first contained plants from the Lower and animals from the Upper Gondwánas. The former I was able to include in the list of localities in my paper (now in the press) on the Damuda-Panchet flora¹; they all were of the Raniganj (Kámthi) horizon, while the animal remains were of the Maleri horizon of the Central Provinces.

The second collection contained Lower and Upper Gondwána plants, many of great interest; it arrived too late to enable me to insert the localities of Lower Gondwána fossils in the alphabetical list in my detailed work.

This collection was much larger, and contained fossils from many more horizons, also several new species of plants. In anticipation of full description and illustration I may now give a brief notice of them, so far as they are known with certainty. I shall enumerate them according to the horizons, and within each horizon from each locality. The horizons I have put down as Mr. Hughes has provisionally indicated them on his labels; two localities for which there was no horizon indicated, I have placed to such horizons as would be assigned to them by the fossils when compared with already-established classifications. I also include the older collections made by Mr. J. G. Medlicott and later by Mr. C. A. Hackett.

A.—LOWER GONDWANAS.

I. TALCHIR DIVISION.—*Talchir group*.

Goraia, on the Johilla river, near Páli, Singwara district.

Collectio Hughes, 1880.

Equisetaceous stem.—One specimen only, with a fragmentary stem, showing a fine ribbing on the surface, but no joint; may be equisetaceous.

II. DAMUDA DIVISION.

a. *Bardkar group*.

Páli and *Johilla* rivers (junction of), near Páli.

Collectio Hughes, 1880.

Glossopteris communis, Fstm. Of the usual type.

Gangamopteris cyclopteroides, Fstm. There is one leaf which I cannot distinguish from this species.

¹ Pal, Indica, Ser. XII, pt. 2.

Nöggerathiopsis (? *Rhoptozamites*) *hislopi*, Bunb. sp (Fstm.) Numerous leaves of various sizes.

Seeds, small, slightly winged.

I must confess that this flora, small as it may appear, reminds me more of that of the 2nd and 3rd seams of the Karharbári coal-field (Karharbári beds) than of the typical Barákar group. When Mr. Hughes next season takes up work again, he will probably succeed in procuring a few more fossils which may decide the question; in the meantime they may remain with the Barákar group.

b. Raniganj group (and Kámthis).

With this group I include also those localities which Mr. Hughes marked Kámthis. Here also are placed the fossils collected previously by Messrs. J. G. Medlicott and C. A. Hacket. I name first the localities from the northern portion of the field, from the Gopat river area; these constitute also the lower Gondwána fossils of the first collection sent by Mr. Hughes in March 1880. Then follow those in the Sohágpur district.

a. Gopat river area.

Bajbai, 2 miles west of Gopat river, lat. $24^{\circ} 4'$, long. $81^{\circ} 57'$.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Just like the same from the typical Raniganj group, Raniganj field.

Vertebraria indica, Royle. Many nice specimens.

Glossopteris communis, Fstm.

Glossopt. indica, Schimp.

Glossopt. angustifolia, Bgt.

Chanduidol, about 8 miles west-north-west of Bajbai, and about 3 miles west of Marhwás.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.

Glossopteris formosa, n. sp. Raniganj species.

Mahán river (tributary of Gopat river), between Minarra (Mirhara) and Gaja (Ganjar), lat. $23^{\circ} 57'$, long. $81^{\circ} 58'$.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.

Glossopteris communis, Fstm.

Glossopt. angustifolia, Bgt.

Alethopteris comp. *whitbyensis*, Göpp. I have no means to distinguish this fern from the jurassic species.

Angiopteridium.—Two fragments of a *taniopteroid* fern resembling a similar one in the Kámthi beds of the Nágpur area, which I quoted as *Angiopt. comp. mc'clellandi* O. M.

Mahán river, near Minarra (close to the former locality).

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Typical Raniganj form.

Glossopteris communis, Fstm.

Glossopt. indica, Schimp.

Glossopt. retifera, Fstm. Raniganj form.

Glossopt. angustifolia, Bgt.

Alethopteris comp. *whitbyensis*, Göpp. As above.

Mahán river, near Tansar, close to junction with Gopat river, north of the preceding locality.

Collectio Hughes, 1880.

Vertebraria indica, Royle.

Glossopteris sp.

Parasi, west of,—from stream running between Parasi and Kunjwar, about 5 miles east of Gopat river, lat. $24^{\circ} 2''$, long. $82^{\circ} 7''$.

Collectio Hughes, 1880.

Glossopteris, sp. Fragments.

With this area also those fossils contained in our collections have to be included which were collected by Mr. J. G. Medlicott, 1861, and are labelled "South Rewah." The fossils are—

Vertebraria indica, Royle.

Stems.

Glossopteris communis, Fstm.

Nöggerathiopsis hislopi, Bunb. sp. (Fstm.).

Voltzia heterophylla, Bgt. The determination of this species from this coal-field is now confirmed by Mr. Hughes' recent specimens.

Small seeds.

These fossils, however, correspond very much with those of the next following locality, in the Sohágpur district.

β. Sohágpur District.

Hardi, near—about 15 miles south-east-south of Sohágpur, long. $81^{\circ} 30''$, lat. $23^{\circ} 6''$.

Collectio Hughes, 1880.

Vertebraria indica, Royle.

Glossopteris communis, Fstm.

Nöggerathiopsis hislopi, Bunb. sp. (Fstm.).

Voltzia heterophylla, Bgt. Several leaved branchlets, which leave no doubt about this species.

Samaropsis comp. *parvula*, Heer. Winged seeds, known also from other places.

Kuchodhar, about 11 miles west of Sohágpur.

Collectio Hughes, 1880.

Glossopteris communis, Fstm. One leaf peculiarly folded.

Sohágpur, in South Rewah.

Collectio J. G. Medlicott, 1861.

Vertebraria indica, Royle.

Glossopteris communis, Fstm.

Glossopteris browniana, Bgt.

Glossopt. dumudica, Fstm.

Son river, west of Garara, Sohágpur district.

Collectio Hacket, 1872.

Fossils in a dark greenish-grey sandy shale. Considering the fossils, I placed this locality with the Raniganj (Kámthi) group, which now by Mr. Hughes' fossils from the same locality (see next locality) is further confirmed.

The fossils were—

Vertebraria indica, Royle.

Macrotaeniopteris feddeni, Fstm. Like the same in the Kámthis of the Nágpur area.

Glossopteris communis, Fstm.

Dictyopteridium (?) sp.

Son river, near Gúrúrú (as written by Mr. Hughes—Gururu on the Indian Atlas) about 1 mile east of Son river, long. $81^{\circ} 23''$, lat. $23^{\circ} 28''$.

Collectio Hughes, 1880.

This is evidently the same locality as that above mentioned of Mr. Hacket. Mr. Hughes' fossils are in two kinds of shale, one dark greenish-grey sandy, like in Mr. Hacket's specimens; the other light yellowish-grey soft clay-shale.

a.—Dark greenish-grey shale—

Schizoneura gondwanensis, Fstm. Raniganj type.

Glossopteris communis, Fstm.

Glossopt. indica, Schimp.

Squamæ gymnospermorum.

These fossils leave no doubt about the Raniganj horizon of this bed, as determined already before by me from Mr. Hacket's specimens.

b.—Light yellowish-grey shale.

Glossopteris angustifolia, Bgt.

Rhipidopsis, n. sp., like in the Kámthis on the South Godáviri (Kunlacheru, originally a genus in the Russian Jura of the Petschora country).

Son river, opposite Sarsi.

Collectio Hughes, 1880.

Schizoneura gondwanensis, Fstm. Very big leaves (or, better said, portions of the leaf spath.)

Glossopteris browniana, Bgt.

These fossils leave indeed no doubt as to the establishment of the typical Raniganj group in this region, as is especially illustrated by the numerous occurrence of *Schizoneura gondwanensis*, Fstm., and several species of *Glossopteris*,

occurring mostly in the Raniganj group. We can in fact say, *Schizoneura* is the characteristic feature of these localities in South Rewah, and is more widely distributed here than *Vertebraria*, as out of eleven localities, *Schizoneura* occurred in six and in great numbers, while *Vertebraria* was found only at five localities. Of other fossils I would specially point out the following:—

Macrotæniopteris feddeni, Fstm. } both of the typical Raniganj
Glossopteris formosa, n. sp., *retifera*, Fstm., } group.

Alethopteris.—There are two pinnæ of an *Alethopteris* which has to be referred to the group of *Al. whitbyensis*, Göpp. A fragment of an *Angiopteridium* has to be referred to *Ang. mc'Clellandi*.

Voltzia heterophylla, Bgt., which we already know from the Karharbári beds, is here again represented in the Raniganj group, and not rare.

c. Supra-Damudas.

On the labels of several fossils from two localities Mr. Hughes has indicated the horizon as "Supra-Damudas." To judge, however, from the fossils and from petrographical character of the specimens, the fossils indicate lower Gondwânas, although representing perhaps two horizons.

Daigaon, on the Johilla river, about 4 miles north-west of Páli.

Collectio Hughes, 1880.

Vertebraria indica, Royle.

According to our present knowledge, *Vertebraria* is especially typical of the Damuda division,¹ and in default of other fossils, I would consider this locality to belong to this division; it may be Raniganj (Kámthi) group.

Parsora (south tolah), near Beli, about 6 miles north-north-east of Páli.

Collectio Hughes, 1880.

The fossils from this locality are very interesting, especially one new species. They are preserved in a red-brown, highly ferruginous, micaceous shale, completely agreeing with the rock in which Mr. V. Ball's fossils from Latiahar, in the Auranga coal-field, are preserved, which as to the horizon² were left undecided, although Mr. Ball thought that they are probably "Mahádevas." Considering, however, the fossils, amongst which there is *Vertebraria* and *Glossopteris*, I treated this locality³ as belonging to the Panchets, and it might be the same case with the present locality in South Rewah, and the more so as the fossils would perhaps support that view.

The fossils are—

Danæopsis.—A new species—in numerous specimens.

Of this genus there were hitherto known with certainty only two species,

¹ There are several specimens known from the Karharbári beds of the Karharbári coal-field and also from a doubtful locality in the Auranga coal-field, which probably is Panchets, but, as a rule, it is a fossil of the Damudas.

² Ball, Mem. Geol. Survey of India, Vol. XV, pt. 2, p. 89.

³ Pal. indica, Ser. XII, pt. 2, p. 9. (To be issued shortly.)

D. marantacea, Heer, from the German Keuper (Upper Trias), and *Danæopsis rajmahalensis*, Fstm., from the Rájmahál group in Bengal (Rájmahál hills). The present species differs from both. It is a much larger form than *D. rajmahalensis*, Fstm., as is especially seen from the thickness of the rhachis and the midribs of the pinnulæ; the veins also have another direction in *D. rajmahalensis*, passing out at a more acute angle from the rhachis and running straighter to the margin. *Danæopsis marantacea*, on the other hand, is again bigger than our present species, the whole frond appears much larger, the pinnulæ longer, the midribs thicker, and especially the top pinnulæ much larger. There are two specimens in Mr. Hughes' collection, showing the top pinnula, which is shorter than the other pinnulæ, while in *Dan. marantacea*, Heer, the top pinnula was equal in size to the others. I refer especially to Schimper's figure Tr. d. Pal. végét., Pl. XXXVII. The secondary veins in *Dan. marantacea* agree well with those in our present species.

But there is an important character in our present species of *Danæopsis*; the primary rhachis of the frond is dichotomously forked, as is shown distinctly by about six specimens; the pinnulæ at the beginning of the fork on the inner side being represented by lobes only. Below the furcation the pinnulæ are also only small. We shall have to take this present species as intermediate between *D. rajmahalensis*, Fstm., and *D. marantacea*, Heer, with closer relation to the latter. All other details will be given subsequently with illustrations. It will be described as *D. hughesi*.

Thinnfeldia comp. odontopteroides, Moor. sp. There are three fragments of fronds, with forked rhachis, which have entirely the aspect of *Thinnfeldia odontopteroides*, Moor. sp. A similar fern was already brought by Mr. Griesbach from the Panchets of the Ramkola coal-field, and this plant would be a support for the view of the locality under discussion being of the same horizon.

Neuropteridium, sp. There is a portion of a frond which appears to be single pinnate and belongs to Professor Schimper's triassic group of *Neuropteris*, distinguished as *Neuropteridium*. We know already one species from the Karharbári beds. The present one appears to be different.

Nöggerathiopsis hislopi, Bunb., sp. Portions of large leaves. This species is known from the whole Talchir and Damuda division.

This is certainly a very interesting association of forms, but it no doubt shows that this locality has to be considered as belonging to the Lower Gondwánas, probably Panchets, but *Danæopsis* would be another form helping to bridge over the break between the lower and upper Gondwánas.

B.—UPPER GONDWÁNAS.

a. MALERI BEDS.

The most important discovery made by Mr. Hughes is, I think, that of the Maleri horizon (of the Godávári basin) in South Rewah. It is undoubtedly established by numerous bones of land animals, the same as those in the Central Provinces.

Tiki, about 6 miles south of Beohari, long. $81^{\circ} 25'$, lat. $23^{\circ} 56'$.

Collectio Hughes, 1880.

Parasuchus hislopi, Huxley (MSS.) represented by portions of jaws, several teeth, numerous fragments of dermal scutes, vertebræ, and other bones. They represent an animal about equal in size to that of the Maleri beds in the Central Provinces.

Hyperodapedon, sp. Jaws, apparently of the same animal as that of the Central Provinces, but three of the jaws are larger than any hitherto known from the latter place.

Unio, sp. Several specimens of a small *Unio*-like shell also occur.

b. JABALPUR GROUP.

There is another horizon of importance in this coal-field, as it contains besides most of the Jabalpur plants of the Sâtpura basin, also others, and especially one species characteristic of, and hitherto only known from, the intermediate beds¹ of the upper Gondwânas on the south-east coast of India.

Bansa, on the Machrar river, about 6 miles south-west of Chandia.

Collectio Hughes, 1880.

Alethopteris whitbyensis, Göpp. Typical form.

Alethopteris indica, O. M. Probably only a larger variety of the former.

Alethopteris medlicottiana, Fstm. The same typical form as from near Jabalpur.

Besides these, there are three other ferns which require further examination.

Podozamites lanceolatus, L. & H. Numerous specimens.

Ptilophyllum cutchense, Moor., in dark sandy shale, resembling similar shales from the Sher and Hard rivers.

A cycadeaceous fruitleaf?

Taxites tenerrimus, Fstm., a Jabalpur group species.

Taxites planus, Fstm. At first described from the Ragavapuram shales, the Sri-permatur group, and the Vemáveram shales, now here represented by several specimens, one a very fine one. I think we have to consider this species as surviving from these intermediate beds on the south-east coast into the Jabalpur group of South Rewah; it is not met with in the Jabalpur group of the Sâtpura basin.

Brachyphyllum mammillare L. & H., completely the same form as in the typical Jabalpur group near Jabalpur.

Echinostrobus rhombicus, Fstm.

Araucarites cutchensis, Fstm. The same as in Cutch and the typical Jabalpur group.

Ginkgo, sp., a small leaf with a thin stalk.

Some other coniferous branches.

It will be very interesting to learn from Mr. Hughes' descriptions in what relation is Jabalpur group is to the Maleri beds of Tiki.

To make this list of fossils from South Rewah complete, I have still to quote

¹ Ragavapuram shales, Sripermatur group, Vemáveram shales.

a few fossils which in 1872 were brought by Mr. Hacket. They were already mentioned, and some figured in my Jabalpur Flora¹ and referred to as from "South Rewah." I have since found a label referring to these South Rewah fossils and giving some information as to the locality.

Chandlia, small nadi south of,—South Rewah, Singwara district.

Collectio Hacket, 1872.

1877. Feistmantel, Flora of the Jabalpur group, etc, Pal. Ind., IX., 2.

Alethopteris medlicottiana, Fstm., a small specimen not mentioned in my Jabalpur flora, found subsequently, will be figured together with Mr. Hughes' specimens.

Sagenopteris ? sp.,² Feistm., l. c., p. 10, Pl. III, fig. 6.

Podozamites lanceolatus, L. & H., l. c., p. 11, Pl. III, figs. 7, 8, 11, 12.

Poëczamites spatulatus, Fstm., l. c., p. 12, Pl. IV, figs. 11, 12.

Araucarites cutchensis, Fstm., l. c., p. 16, Pl. XIV, figs. 11—13.

Echinostrobus expansus, Schimp., p. 17, Pl. XI, fig. 5.

Ech. rhombicus, Fstm., l. c., p. 18, Pl. XI, figs. 6—11.

FURTHER NOTES ON THE CORRELATION OF THE GONDWANA FLORA WITH OTHER FLORAS
by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

Flora of the Kusnezsk basin and Tunguska river, Siberia.

In a short note in the first number of this year's Records with reference to a preliminary paper of Mr. Schmalhausen on the jurassic flora of the Kusnezsk basin and Tunguska river, I compared the Indian (and Australian) leaves formerly known as *Nöggerathia*, but distinguished by me as *Nöggerathiopsis*, with the Siberian *Rhoptozamites* Schmalh, which also had at first been described as *Nöggerathia*. I have since received Prof. Schmalhausen's work, illustrated with sixteen plates,³ and I would now complete my reference to his observations.

My supposition of our *Nöggerathiopsis* and the Siberian *Rhoptozamites*, Schmalh. being in closest relation is now confirmed. The size and form of the leaves and the characters of the veins is in both genera completely identical; the only difference between them being that the veins in *Rhoptozamites* are closer. This character might eventually be taken as a specific distinction only, while yet the two genera might be identical. This of course is not necessarily of much consequence regarding the correlation of the two formations in which these genera are found; but their close generical relation (perhaps identity) is of great importance in fixing the systematical position of the one from the other.

Prof. Schmalhausen places his *Rhoptozamites*⁴ (which name by itself implies the

¹ Pal. Indica, Ser. IX, pt. 2.

² In the paper quoted the locality of this fossil is by mistake given as Jabalpur instead of South Rewah.

³ Beiträge zur Jura-Flora Russlands, von Joh Schmalhausen, in Mem. de l'Acad. Impér. des Sc. de St. Petersburg VII, Ser., Tome XXVII., No. 4.

⁴ ῥίπτω- to cast off, and *Zamia*—botanical name.

cycadeaceous nature) with the *Cycadeaceæ*, together with well-known cycadeaceous genera, such as *Otenophyllum*, *Dioonites*, and *Podozamites*; in the first instance these leaves (*Rhoptozamites*) which are described as pinnate (I used for the Indian leaves the expression *foliis biserialibus*), are compared with forms of *Podozamites*, as I also had done with the Indian leaves, before Prof. Schmalhausen's paper was in my hands.¹

The Siberian leaves are described as deciduous, being generally found as single leaves; this certainly was also the case with the Indian forms, as all the leaves hitherto found were detached (*l. c. p. 24*).

Prof. Schmalhausen also points to the unequilateral shape of the leaves, adducing this as a character in favour of the view of the fronds having been pinnate, in which case the leaves generally met with would be the pinnulæ. A similar character had already been observed in the Indian leaves from the Nágpur area by Sir Ch. Bunbury, who expressed it by saying the leaves were "not symmetrical, but very slightly oblique," and I confirmed it subsequently from the Karharbári specimens (*l. c. p. 24* and figures); it is seen also in all the specimens from the other localities, so that we may fairly use this character in support of the view that the detached leaflets belonged to a pinnate frond. Amongst the Indian specimens not one has been observed showing the connection with the stalk; but there are several specimens (from the Raniganj field, from South Rewah, and the Sátputra basin) which show such an association of two or three leaves as forcibly reminds us of an arrangement of the pinnulæ in a pinnate leaf.

With this close generical relation (eventually identity) of *Rhoptozamites* Schmalh. and *Nöggerathiopsis*, Fstm. in view, we are completely justified in placing these latter also with the order *Cycadeaceæ*, family *Zamiæ*, and have to compare them, as I have already done, with the fossil *Podozamites*, which is essentially a mesozoic and prominently jurassic genus, known in the Upper Gondwánas in India, in the Kusnezh basis in the Altai (in association with *Rhoptozamites*), and in the jura of E. Siberia and in the Amur countries; also numerous in Europe. This cycadeaceous plant, *Nöggerathiopsis*, is rather numerous in the Lower Gondwánas; it occurs in—

THE TALCHIR DIVISION	...	{	Talchir group: rare (Deoghur).
			Karharbári beds: very numerous both in the Karharbári field (Nos. 1, 2, 3 seams) and in the Mohpáni coal-field.
DAMUDA DIVISION	...	{	Barákar group: Ráukola coal-field, South Rewah coal-field, Sátputra basin (Shahpur and Umrét).
			Raniganj (Kámthi): Raniganj coal-field (rare); South Rewah (frequent).
			Nágpur district (Kámthis): numerous.

This *Nöggerathiopsis* forms in the Lower Gondwánas just as prominent a feature as *Pterophyllum*, or *Cycadites*, or *Podozamites* does in the Upper Gondwánas, and consequently the great break between the Lower and Upper Gondwánas is

¹ Pal. Indica, Ser. XII, 1, p. 23.

now—as regards at least the *Cycadeaceæ*—to a great extent removed. This break is still more filled in by the interesting circumstance (to be noticed presently) that there are other forms, both in the Lower and Upper Gondwánas, which find their close analogies or identical representatives in the Jura of the Altai and Siberia and elsewhere.

Before proceeding to this point, the systematical position and analogies of *Nöggerathiopsis*, Fstm., may be therefore expressed thus—

CYCADEACEÆ.

a. ZAMIEÆ.

<i>Nöggerathiopsis</i> , Fstm.	<i>Nöggerathiopsis</i> , Fstm.	<i>Rhoptozamites</i> , Schmalh.	<i>Podozamites</i> , Br.
Palæozoic—Australia (N. S. Wales).	Lower Gondwánas, India.	Jura—Altai and the Tunguska River.	Jura—(Upper Gondwánas, in India, Siberia, and elsewhere.

The jurassic flora described by Professor Schmalhausen from the Altai M^{ts} and the Tunguska river,¹ is further interesting, as it contains several forms partly identical with and partly closely related to species in the Upper and Lower Gondwánas of India, representing thus, so to speak, an amalgamation of parts of both. Taking also the other jurassic floras of E. Siberia and the Amur countries (Heer) into consideration, we can establish the following list of correlations:—

GONDWANA SYSTEM—INDIA.

JURA—SIBERIA, ETC.

a. UPPER GONDWANAS.

Alethopteris whitbyensis, Göpp. Kach and }
Jabalpur group; Sripermatur group }
(Sripermatur and Vemáveram). }
Alethopteris indica, Oldh. and Morr. Sri- }
permatur and Rájmalál group. }
Dicksonia bindrabunensis, Fstm. Rájmalál }
group. }
Podozamites lanceolatus, Schimp. Jabalpur }
and Sripermatur group. }
Anomozamites (Pterophyllum) princeps, O. M. }
Rájmalál group. }
Anomozamites lindleyanus, Schimp. Sriper- }
matur group. }
Gingko lobata, Fstm. Jabalpur group.
Czekanowskia ? and *Phönicopsis* ? Jabalpur }
group. }

Asplenium whitbyense, Heer (Siberia and }
Amur countries). }

Dicksonia concinna, Heer. Amur countries.

Podozamites lanceolatus, *eichwaldi*, etc. }
E. Siberia and the Altai. }

Anomozamites schmidtii, Heer. Amur coun- }
tries. }

Anomozamites lindleyanus, Heer. E. Siberia.

Gingko digitata, Heer. E. Siberia and Altai.
Czekanowskia and *Phönicopsis*. Heer. Altai,
E. Siberia, Amur countries.

b. LOWER GONDWANAS.

Phyllothea indica, Bunb. Raniganj (Kánthi)
group.

Stems of the same.

Phyllothea sibirica, Heer, and *Phyll.² deli-*
quescens, Schmalh. (Göpp. sp.). Altai and
E. Siberia.

Stems, quite similar (See Schmalhausen, *l. c.*
Pl. I, fig. 2). Altai.

¹ I leave the flora of the Petschora country out of comparison here, and refer to the Asiatic (Siberian) forms only.

GONDWANA SYSTEM—INDIA—*contd.*

Phyllothea robusta, Fstm. Raniganj group
(Rájmahál hills).

Alethopteris whitbyensis, Göpp. Raniganj }
group.
Alethopteris lindleyana, Royle. Raniganj }
group.

Cyathea comp. *tchihatcheffi*, Schmalh.
Barákars.

Dicksonia hughesi, Fstm. Raniganj group.

Glossopteris gangamopteris. Lower Gond-
wánas.

(*Rubidgea*. Karoo beds, S. Africa).

JURA—SIBERIA, ETC.—*contd.*

Phyllothea schtschurowski, Schmalh. Altai.

Asplenium whitbyense, Heer. (Siberia, Amur
countries.)

Cyathea tchihatcheffi, Schm., Altai.

Dicksonia concinna, Heer. Amur countries.

Zamiopteris glossopteroides, Schmalh. Altai.
This fern resembles strikingly (and is
also by Schmalhausen compared with)
Glossopteris in shape and distribution of
veins, but has no midrib and no anastomoses.
Other specimens resemble *Gangamopteris*
angustifolia, but they again want the
anastomoses. The most closely related
genus is *Rubidgea* from the Karoo beds;
there is hardly any distinguishing character,
but they are not to be mistaken for my
Palaovittaria.

Rhoptozamites güpperti, Schmalh. Altai,
Tunguska.

Samaropsis parvula, Heer. Altai (See Schmalh.
l. c., Pl. IV, fig. 3 *b.*) E. Siberia.

Squamæ gymnospermarum. Altai, Tunguska
(Pl. XV, figs. 14, 15, represent forms of the
Raniganj group, while Pl. XVI, fig. 22,
represents a Barákar form).

This list speaks for itself, and there is nothing surprising in it when we consider the close relations of the various groups of the Gondwána system as independently observed. We have in addition the occurrence of *Glossopteris* in the Upper Gondwánas, the representation of *Podozamites* in the Upper, by *Nöggerathiopsis* in the Lower Gondwánas, the occurrence of *Glossopteris* and *Vertebraria*, in a horizon in the Auranga coal-field, which Mr. Ball could not assign to any bed of the Lower Gondwánas, but thought it should belong to the Máhadevas (Upper Gondwánas), although I think it may represent the Panchet group, etc. There is also a fine collection of plants made by Mr. Hughes in South Rewah, which will further illustrate this intermingling of the flora just on the boundaries between the lower and upper beds of the Gondwána system.

These relations, which no doubt will find further illustration in course of the more detailed work of the Survey, show well the fitness of combining all the beds from the Talchir group up to the Jabalpur and Kách group under one collective designation, for which the name *Gondwána system* was very happily chosen.

ADDITIONAL NOTE ON THE ARTESIAN WELLS AT PONDICHERRY, by W. KING, Deputy Superintendent (Madras), Geological Survey of India.

While my paper in the last number of the Records was in press, I received some further details from Mr. Poulain, giving corrected heights and discharges of water columns in the Savana and Ūpallem wells, which were inserted in the body of the paper, but not in the introduction. Unfortunately I misunderstood some of these corrections, as they are explained in a later letter received from Mr. Poulain, and therefore it becomes necessary to draw attention to the following errors:—

On page 113, line 33, for 'three' read 6·5; for '44' read 30.

On page 114, line 16, for 'nearly 1 foot' read 3·28 feet.

On page 120, line 21, for '44,' read 30; for 'one' read six.

These corrections are made from a later note published in the '*Travaux des Commissions Locales*' which my friend Poulain has furnished since the publication of my paper, and of the existence of which I was unaware until now. A translation of this note is now appended; it follows as number five on the 'Experiences of Mr. Poulain' given in Appendix II of my paper.

Experience at "Savana."

"The latest information given on the progress of the borings up to the 11th September left the depth at 52·68 meters and the discharge at 90 litres a minute.

"The discharge increased proportionally with the disengagement of the sands at the bottom of the ascending column. It is now at 135 litres a minute. During the working the water had a very marked yellow-ochrey colour, and it became limpid as soon as the work was stopped. The actual depth is 53 meters.

"We have verified the hydrostatic level of this source, and as the ground surrounding our well has lately been raised by the heaping up of the excavated material, we have been obliged for exactness to take the level of the old soil. This having been ascertained, the rise is 1·96 meters above the soil. The water has not lowered from this point.

"Regarding the uses to which the water of the 'Savana' well may be applied, we cannot do better than reproduce in text the official analysis given by Mr. Castaing, Chef de Service Pharmaceutique, at the requisition of the Ordonnateur:—"Depth of the well, 52·68 meters. This water is limpid, colourless, inodorous, agreeable to the taste, and fresh. It contains 26 centigrammes of saline residue to the litre, composed of earthy chlorides and sulphates. It marks 7 degrees on the 'hydrotimètre.' It boils vegetables well, dissolves soap, and does not contain any organic matter. It possesses all the requisite conditions of a potable water, and is adapted for all culinary and industrial uses. It will leave only a feeble deposit in boilers if it be allowed to settle for a short time."

"From an agricultural point of view, and in the opinion of several native cultivators, the quantity of water now furnished by the well would be sufficient

for the cultivation of 12 cawnies of rice fields, or above double this superficies for inferior (*menus*) grain.

"The sinking of the tube will be continued for some meters more or so to penetrate further into the water sheet."

Pondicherry, 30th September 1877.

The search for these water sources is still being prosecuted at Pondicherry and in the neighbourhood, and this has been attended with fair success; but the Government boring in the *Ville Noire* is now in abeyance, as it was found impossible, with the appliances at hand, to drive the tube down beyond the depth attained, namely, about 550 feet, and there has been no further rise of water. It is proposed to run down a tube of smaller diameter, when opportunity offers.

In the meantime, a new well has been started by Government in the village of *Ariankúpam*, at about 300 yards from the south or right bank of the river of that name, which, however, is so far a failure also, though a rising sheet of water was tapped at a comparatively slight depth.

Here the level in the surrounding wells is at 16.40 feet below surface soil, perhaps about the mean level of *Ariankúp* river, which is tidal.

At 32.28 feet, water rose to a height of 3.83 feet over the surface soil. This water appears to have been the purest yet obtained in this way. After three days the discharge ceased, and the water disappeared from the tube. Mr. Poulain conceived this might be attributable to accident; that the hole made by the borer was larger than the tube, and that the water had passed away between the latter and the surrounding deposits and been absorbed into permeable beds above, and on this he suggested to Government some means for meeting the mishap. The Engineer preferred to proceed with the boring and the sinking of the tube, and now a depth of 157 feet has been reached without a further water sheet having been struck.

The deposit latterly pierced is a clay or lithomarge of a reddish colour, with veins or streaks of white, such as is occasionally met with in the sandstones of Pondicherry and Cuddalore, below which, according to one account, is a conglomerate of a greyish colour and hard enough to be taken as an approach to beds of that series.

It is indeed very possible the Cuddalore sandstones may have been touched, or that the borer is close on them, it being not at all unlikely that a sub-alluvial ridge or plateau of these beds may exist at no great depth between the *Ariankúp* and *Puncar* rivers, there being here a gap of rather unexplainable width in the red sandstone belt.

The general succession of beds in this boring is:—

1. Sandy soil and sands,
2. Thin band of black clay,
3. Whitish clay,

but this requires confirmation.

A private boring was put down some time ago at *Mudeliarpot*, a small village in the vicinity of the Colonial Gardens and the *Savana* filature, and a rising

these of water was tapped at 49·20 feet, which remained at nearly a foot below surface soil. The rise increased on the boring being carried deeper, and eventually stood at the level of the ground, which is, however, 1·47 feet above the surface level at Savana, that is, 10·47 feet above sea-level. The discharge is 17·6 gallons a minute, but the tube is filled with sand for more than 3 feet from the bottom, which when cleared may allow of an increased flow.

A block of wood or a tree trunk was met with embedded in the sand at 72 feet, which disappeared, however, in some unaccountable manner after being cut at with the jumper for two or three days. Mr. Poulain seems to think that it may have been carried off by the current of water at this horizon; but such freedom of motion is hardly conceivable in alluvial strata;¹ the trunk has been probably just shoved aside.

The beds traversed are:—

	Feet.
Vegetable mould	1·96
Sandy soil	31·65
Black clay	7·87
Coarse and fine sand	39·36

This succession would tie in well with the sections exposed by the Savana, Jardin d'Acclimatation, and Upallem borings, though the clay band has thinned out a good deal from what it is at the Savana well.

Another well was commenced last year in the village of Archiwakum, about 7 miles south of Pondicherry, which reached a depth of 144·32 feet, after passing through the following strata:—

	Feet.
Vegetable mould	1·64
Red sandy soil	13·12
Micaceous sand	13·12
Very hard clay of yellowish colour, streaked with veins of light green clay, with some layers of white sand . . .	111·52
"A sort of Molasse" of reddish yellow colour . . .	3·28
Sand ²	

The water ascended from the later deposit to within 6·56 feet of the surface soil, the wells of the neighbourhood having their water at 13·77 feet below surface, or perhaps about sea level.

This boring is stopped for the present, as the pipe cannot be forced down any further; but a second pipe is to be inserted in this, after which better progress may be made.

The boring in Mr. Cornet's compound, which was noticed in my previous paper (*l. c.* p. 115), has been again continued with the hope of finding a sheet of better water. It is, I believe, nearer the sea than any of the other wells to the south, and a certain oscillation of the hydrostatic level of that sheet was observed

¹ Free and cavernous passages are, I fancy, only possible in hard and rocky strata, and most frequently in soluble rocks, such as limestones.

to be apparently in accord with the rise and fall of the tide; but I have received no further information on this point. As bearing on this an important fact was brought to my notice by His Grace the Duke of Buckingham in connection with the tidal observations made at Madras by Colonel Baird, which shows that there is very free percolation of fresh water into the sea on the coast there. It appears that a well or cylinder was sunk in the vicinity of the harbour works for a tidal gauge, and it was found that the water in this well became fresh in a very short space of time. This indicates a head and large supply of water which should be struck by borings of no great depth. It may be that a stratum of this kind has been tapped by all the wells, except that of the *Ville Noire* and in the neighbourhood of Pondicherry, the few tubes put down having offered a freer exit than that existing, not only on the sea face, but also in the beds of the rivers near the coast.

This observation at Madras implies that the flow of water shows itself at a very shallow depth, but the free percolation must be deeper than this under the Madras plain, for it is well known that at the ordinary depth to which open wells are made here, there is not free communication of their waters. For instance, in many compounds, wells have been dug at various spots, only some of which contain fresh waters. A case in point is that of Mr. Franck's compound on the Mount Road, an area of about 3 or 4 acres in which, as far as I remember, 5 wells were dug, most of which gave brackish water, so here in this small space and at a very shallow depth, are seams of permeable strata which can hardly be in free communication with each other.

SALT IN RAJPUTANA, *by* C. A. HACKET, *Geological Survey of India.*

The soil of Rajputana, over wide areas, is impregnated with salt. This is more particularly the case on the western side of the Arvali range of hills, where large quantities of salt are manufactured from the efflorescence developed on the surface, and the water in the majority of the wells is too brackish to drink, and in some places the only drinking water obtainable is from small tanks in which the rain water is collected.

The country on the eastern side of the range, north of Ajmere, is also frequently saliferous, but with the exception of a few places, like Sámbar and Bharápur, not nearly to so great an extent as on the western side. South of Ajmere, on the eastern side of the range, salt is not met with in any quantity.

So many descriptions of the sources and process of manufacture of the salt of Rajputana have been published, of which the most complete are those in the *Gazetteer of Rajputana* and the *Reports on the Administration of the Inland Customs Department*, that it is unnecessary for me to enter into these particulars. The object of this paper is to give a brief description of the rocks in the neighbourhood of these salt sources with reference to the possible origin of the salt.

The salt is obtained from four sources—

- 1st.—From the large shallow lakes, from which great quantities of the best quality of salt are obtained.
- 2nd.—From earth-works, or the collection of the efflorescence on the surface of the soil, re-dissolving it in pits, and allowing it to evaporate in shallow pans.
- 3rd.—From weak brine wells, as at Bhartpur.
- 4th.—From the deposits formed in old beds of rivers.

The earth-works used to be exceedingly numerous, particularly on the western side of the Arvalis, but they are now mostly abandoned. Large quantities of salt were also obtained at Pachbadra, from pits sunk in a hollow supposed to be an old bed in the Lúni river.

Under the new salt revenue regulations the works at Bhartpur are closed, but they were once extensive. In the Gazetteer of the Bhartpur State, salt figures as more than two and a half lakhs of rupees in the revenue receipts for 1873-74. The principal works were close to the west of the city, where large evaporating areas were supplied with brine drawn from wells in the open plain. The nature of the source is altogether obscure: there is no natural surface efflorescence or any other sign to indicate the salt below: rich cultivation is carried on close to the brine wells, and in other wells at a short distance off sweet water stands at about the same level. At the time of observation (December 1865) the briny water was only 20 feet from the surface, and was said to be 20 to 30 feet deep. A well then being worked was said to have been in use for 28 years, without sensible change in the quality of the water. In one unlined well the 20 feet over water level was seen to be one unbroken mass of sandy kankary clay, of the type so general in the great alluvial deposits of the plains.

At present the manufacturing operations are almost restricted to the salt lakes, the most important of which are—

Sámbar on the borders of Jeypore and Jodhpore—

Kachor-Rewasa	...	...	...	...	in Shaikhawáti.
Dídwána and Phalodi	...	...	...	...	in Jodhpore.
Lonkára Sur	...	...	...	...	in Bikaner.

But as I have visited only the first three of these lakes, my remarks will be confined to them.

The Sámbar Lake—is situated on the eastern side of the Arvali range (Indian Atlas sheet 33, S. E.). Its greatest length is about 20 miles, and the average breadth is about 5 miles. Its greatest depth, near the centre, at the end of the rains, is seldom more than 3 feet.

The Arvali range near the lake consists of several broken parallel ridges of quartzite, some of them rising to a height of 1,000 feet above the level of the plain. The ground between the ridges is not much higher than the level of the plain to the east, and is mostly covered by the blown sand.

The country east of the range, and surrounding the lake, is covered by long ridges of sand running in an east and west direction, some of them upwards

of 100 feet in height above the level of the lake; thus the northern shore of the lake near Gudha is 1,184 feet above sea level, whilst An, about 1 mile from the southern shore, is 1,262 feet, Singla, 4 miles from the southern shore, 1,292 feet, and Duri, about 6 miles east of the lake, 1,363 feet above sea level.

These ridges of sand are formed by the west wind bringing the sand through the gaps in the ridges of quartzite forming the range. The lake is merely a hollow in the sand, lower than the surrounding country, from the fact of its lying under the lee of one of these high ridges and so protected from the blown sand.

The drainage area of the lake is about 2,200 square miles.

Of the two principal streams that flow into the lake, one takes its rise about 50 miles to the north-east, and the other near Ajmere about 40 miles to the south.

As the lake becomes dry, a deposit of black mud is left at the bottom, which, when dry, contains numerous small crystals of salt. Mr. Adams, the Assistant Commissioner of Inland Customs at Sámbar, gives the following section of a pit sunk 10 feet deep in the bottom of the lake near the low water level opposite Japog. "After penetrating through a layer of about one and a half feet in thickness of the dark greyish sand which, when covered with water, becomes the black mud of the lake, about half a foot of quicksand with brine was met with. Below this a black micaceous sand occurred, which was much decomposed on the surface, but which became gradually harder downwards. A very similar stratum of micaceous schists¹ occurs in wells about 4 miles to the south-east of Japog." (Inland Customs Report, 1870-71, p. 113).

Outcrops of these schists occur on the shores of the lake near Japog and several other places. They belong to the Arvali series of rocks, of which mention will presently be made.

Calcareous deposits of considerable thickness are of frequent occurrence round the shores of the lake. They are well developed near Sámbar and Nanwa. These deposits are apparently formed by the infiltration of water into the blown sand forming the banks of the lake. Upwards of 20 feet of this concretionary limestone is exposed in a well sunk on the southern shore of the lake near Kotarsina.

The following statements relating to the specific gravity of the lake water is taken from Mr. Adams' report for 1870-71 (*l. c.* p. 115):—"The specific gravity of the lake water during the past rains never was less than that of sea water, the specific gravity of sea water being given as 1·03, while the lake water on 30th July gave 1·03. In August about 5 inches of rain fell, and as the evaporation, owing to the humid state of the atmosphere, was slight, the specific gravity was the same as that at the end of July. During September the specific gravity kept at 1·04; in October it increased from 1·05 to 1·07; in November it varied from 1·08 to 1·10; in December, owing to some slight showers of rain, it was reduced to 1·095; in January it increased from 1·11 to 1·14; in February it increased from 1·15 to 1·20, and at this specific gravity salt began to deposit. No difference of gravity was at any time observed in the brine taken from the surface and that taken from the deepest part of the lake.

¹ It is to be presumed that the 'sand' of the preceding sentence is decomposed schist.

"The specific gravity of a saturated solution of salt is 1·2046, but on the 9th March the specific gravity of the highly concentrated lake brine was 1·22, and on the 30th March 1·245. In this state the chemical solution is so dense that precipitation in the form of truncated pyramid-shaped crystals (the well-known form of the Sámblhar salt) is constantly occurring, until a layer of salt about 2 inches in thickness overlies the mud of the lake."

Dr. H. Warth gives the following analyses of the lake brine (*l. c.*, 1871-72, p. 155):—

"The samples examined were as follows:—

1. Lake brine—

A.—Common brine from the lake, 10th December, 100 yards from the shore near Japog.

B.—The same brine artificially saturated.

C.—Brine from Japog, 24th January.

2. Subterranean brine, or percolation brine, taken from diggings in the lake bed at places where the surface water had receded—

A.—Brine from reservoir in walled enclosure No. 2, 10th December.

B.—Brine from the same, on 13th January.

C.—Brine from a hole made on the shore near Japog, 10th December.

3. Mother-liquor—Residue brine from the manufacture of salt in *kyaris*—

A.—Mother-liquor from walled enclosure, No. 2, December 1869.

B.—Mother-liquor from the same, 17th January 1870.

C.—Mother-liquor from walled enclosure No. 1, 26th January 1870.

Analyses.

			Lake Brine.			Subterranean Brine.			Mother-Liquor.		
			A.	B.	C.	A.	B.	C.	A.	B.	C.
Dry residuum	...	...	21·9	27·1	27·8	22·7	20·8	20·1	30·6	30·4	30·4
Water	...	...	78·0	72·6	72·2	77·5	79·3	80·0	68·8	68·8	68·4
Chloride of sodium	..	..	19·9	24·6	24·8	19·7	17·5	17·3	19·1	20·5	19·4
Sulphate of soda	...	...	1·6	2·0	2·6	2·5	2·5	2·5	7·1	9·4	6·5
Carbonate of soda	...	...	0·4	0·5	0·4	0·5	0·8	0·3	4·4	0·5	4·5
TOTAL	...	...	99·9	99·7	100·0	100·2	100·1	100·1	99·4	99·2	98·8
Percentage of foreign salt in dry residuum	...	...	9·1	9·2	10·8	13·2	15·9	13·9	37·6	32·6	36·2
Average	...	...	9·7			14·3			35·5		

Analysis of clay from Lake-bed.—"The sample was taken from the Lake-bed, some feet under the surface, when the reservoir was being excavated, in walled enclosure No. 2, in December 1869.

Water	...	...	...	...	...	38.9
Silica	...	...	...	...	...	25.0
Oxide of alumina, iron, &c.	...	...	...	...	...	8.6
Carbonate of lime	...	...	...	...	...	8.1
" of magnesia	...	...	...	...	...	3.4
Chloride of sodium	...	...	...	...	...	13.1
Sulphate of soda	...	...	...	...	...	2.6
Carbonate of soda	...	...	...	...	...	0.3
TOTAL						100

"Proportion of foreign salts in the soluble substance, 18.1 per cent."

The Didwána salt lake—is situated about 20 miles to the west of the Arvali range and 35 miles from the Sámbar lake in a north-westerly direction. It is about 4 miles long and $1\frac{1}{2}$ miles broad. During the rains there is mostly a foot or so of water in the lake, but which soon dries up. When I was there in November it was quite dry, with the exception of a few patches of mud.

The origin of the lake is similar to that of the Sámbar lake. It is situated under the lee of a short ridge, between 300 and 400 feet in height above the level of the plain, and so protected from the blown sand, which about here forms long ridges sometimes upwards of a 100 feet high, extending in an east-north-east direction. This is also the direction of the longer axis of the lake.

Two dams are built across the lake at about three-fourths of a mile from either end, to cut off the access of surface water.

The mode of procuring the salt differs from that at the Sámbar lake. At Didwána wells of about 6 feet in diameter are sunk in the bottom of the lake to a depth of about 15 feet, the bottom of the well is then pierced to a further depth of 2 or 3 feet, by a heavy iron-shod pole, when the brine rises suddenly to within 4 feet of the mouth of the well, at which level it constantly stands during the hot weather and the rains. When the wells are first pierced large quantities of sulphuretted hydrogen gas are evolved, and even in the old wells the smell of the gas is very strong.

The sections exposed in the wells consist of alternations of sand and sandy calcareous tufa.

The brine from these wells has a specific gravity of about 1.2. It is lifted by the *chanat*, or lever bucket, into shallow pans of about 20 yards square and allowed to evaporate, when the salt is collected.

The manager of the works told me that the cost of manufacture was only Re. 1 for 200 maunds.

The Kachor-Revrassa lake—is situated in Shaikhawáti, about 30 miles north of the Sámbar lake. It is very shallow, and when I was there, perfectly dry, and no manufacture of salt was being carried on.

Geological features.—The rocks forming the Arvali range belong to the gneissic or metamorphic series and the lower transition or sub-metamorphic series. The latter series consists of schists, slates, limestones, and quartzites, and has been called the Arvali series. All the sections across the range show that the rocks have been greatly disturbed, folded, and repeated several times. The dip is always high, seldom less than 70° , and often vertical. The most prominent features in the range are formed by the quartzites, the highest member of the Arvali series; thus, Táragarh hill near Ajmere, 2,855 feet above sea level, is formed of this quartzite, as well as the ridges immediately west of the Sámbar lake, one of which rises to the height of 2,430 feet, and the ridges of quartzite, of the southern portion of the range, south of Todgarh, attain an elevation of upwards of 4,000 feet above the sea.

Complete sections of the Arvali series, from the gneiss to the top quartzites, are exposed both to the south, near Ajmere, and to the north of the Sámbar lake in Shaikhawáti, but in the neighbourhood of the lake only a skeleton of the range is left, consisting almost entirely of vertical ridges of quartzite, the lower and softer slates, schists, &c., having for the most part been worn down below the level of the plain and covered by the alluvium and blown sand.

Several outcrops of the Arvali schists occur on the shores of the Sámbar lake, particularly a few miles west of Sámbar. The only other rocks exposed are portions of two broken, roughly parallel ridges of quartzite, one at the western end of the lake, and the other near the centre, a short distance east of Nanwa. The famous marble quarries of Makrána are situated on the western side of the range, about 10 miles due west of the lake.

No rocks are exposed in the bed of the Didwána lake, but a considerable thickness of slates occurs in the hills a short distance to the west; there are also some hills of quartzite at Kolia and Patan, a few miles distant from the lake.

Besides the metamorphic and sub-metamorphic rocks of which the central range is composed, another series of rocks, the Vindhyan, occur near it on the western side. The eastern boundary of these Vindhyan runs from Sojat to Khátu, at a distance of about 20 miles from the western edge of the range. West from this line they extend almost continuously to the west of Jodhpore. The Vindhyan of this area consist of sandstone, limestone, and conglomerate; they are but slightly disturbed, being mostly horizontal, and seldom dip at a higher angle than 5° . They rest quite unconformably upon the Arvali series. Good sections of this unconformity are exposed both at Sojat and Khátu, where the nearly horizontal sandstone of the Vindhyan rests upon the edges of the vertical Arvali slates.

As no fossils have as yet been found either in the Vindhyan or Arvali series, their age cannot be determined with any certainty. There is a great break between the Vindhyan and the Gondwánas, the next series in ascending order; and as the lowest group, the Talchirs, of the latter are probably permian, the Vindhyan are not likely to be younger than the carboniferous and possibly much older. The unconformity between the Vindhyan and the Arvalis is very great, it is almost necessary to suppose that the Arvali range was formed previous to

the deposition of the Vindhyan, in which case the Arvali series would be of very ancient date, probably cambrian.

The favourite theory to account for the origin of the salt in Rajputana is, that the rocks of the Arvalis belong to the "Permian system," which is confounded with the saliferous rocks of England; and that the salt of this region is derived from some of these beds as yet undiscovered, being dissolved by the rains and rivers and redeposited in the shallow lakes.

I have already shown that both the Vindhyan and Arvalis are older than the permian; but this would not dispose of the assumption that either one or both of these series might contain salt beds. As the lower beds of the Arvali series are covered by the alluvium and blown sand in the neighbourhood of the Sámbar and Didwána lakes, it is impossible to say that salt beds do not exist in that position; but it is evident, from the wide distribution of the salt, that it could not be derived and distributed in the alluvium from one or two local sources, and therefore, if the origin of the salt be in the rock, its occurrence there must be frequent, and the probabilities of detecting it (or traces of it) *in situ* would be very great.

I have examined a very large area occupied by the Arvali series, from the extreme northern end of the Arvali range to within a short distance of Mt. Abu, without finding any trace of a salt deposit, notwithstanding the numerous complete sections of the series that are exposed, from the gneiss to the highest known beds.

There seems even less probability of salt escaping detection in the Vindhyan; for in the very large area covered by them in this region, both to the south-east and to the north-west of the Arvali range, the whole formation is exposed, from its very base, without any contortions to favour the concealment of peculiar beds, yet no trace of a salt deposit has been observed.

The artificial lakes, wells, and rivers afford stronger evidence that the salt is not derived from either the Arvalis or the Vindhyan. There are several large artificial lakes and tanks within the range at elevations greater than that of the plains. The principal of these are the Ana Ságar at Ajmere, situated in an eroded anticlinal fold of the Arvali strata in the centre of the range, Pokhar lake near the western side, and the Rae Samand at Kankroli on the eastern side of the range. The water supplying these as well as the numerous smaller tanks of the range flows over more or less complete sections of the Arvali rocks, and is in all of them sweet.

Of the numerous wells sunk in the Arvali rocks of the range, I do not remember that the water in any of them was brackish.

The Luni river, and its numerous tributaries draining the greater portion and a long length of the Arvali range, contain sweet water as far as the western edge of the range; but after flowing some distance over the plain to the west, the water becomes saline, and salt is deposited on the banks in the hot season, when the rivers cease to flow. At Pachbadra, 35 miles south-west of Jodhpore, large quantities of salt are manufactured in a valley near to, and probably an old bed of, the Luni. The Banas river and its tributaries flowing to the

east, drain a considerable portion of the range, and the waters remain sweet throughout.

The wells sunk in the Vindhyan rocks, on the western side of the range, contain, without exception, sweet water, while those sunk in the alluvium a short distance off contain brackish water.

As it seems improbable that the salt is derived from either the Arvali or the Vindhyan series, the only visible source remaining is the alluvium. It has been suggested that the alluvium is, in part at least, of marine origin, and that the salt lakes are parts of the old sea bottom in which the salt has accumulated. As no good sections of the alluvium west of the Arvali range are exposed, the beds of all rivers being shallow, seldom more than 20 feet below the level of the plain, and as large areas, more especially in the northern portion, are covered by blown sand, it is difficult to produce any direct evidence on this point.

Mr. Blanford found a mollusk (*Potamides layardi*), an inhabitant of salt lagoons on the coast, in one of the salt pools near Umerkot, from which he inferred that an arm of the sea extended as far as this in recent times. But Umerkot is more than 300 miles nearer the sea and several hundred feet lower than the level of the plain near the Sámbar lake. In the portion of the alluvium that I have examined, extending south to 25° north latitude, I have not seen a marine shell; but in several places, in the old banks of the rivers, I have found fresh-water shells of existing species.

In my examination of the alluvium west of the Arvali range, I met with several ridges, many miles in length, of water-worn boulders, often as much as 1 foot in diameter. Nearly all of them were formed of the hard quartzite of the Arvali series, and must have undergone much rolling to reduce them to their present shape. A short distance west of Khátu, and about 35 miles west of the Arvali range, there are two parallel ridges formed of these boulders, about a mile apart at their nearest points and about 6 miles in length, running nearly north and south. How far north they may extend I am unable to say; but to the south they reach in a broken line to the Luni river, a distance of upwards of 70 miles. The boulders sometimes rest upon the Vindhyan, and are frequently isolated in the alluvium. The base of the ridges is never above the level of the plain. The boulders are clearly superficial to the Vindhyan and of comparatively recent origin; but whether they mark the course of a large river or of an ancient coast line, it would be rash at present to decide.

General conclusions.—If the question of origin from rocks underlying the alluvium could be decided from all that is visible of these rocks above the alluvium, and if the whole nature of these covering deposits could be told from what we can see of them in shallow sections at the surface, the answer in both cases would be in the negative, and the only source remaining for the salt would be its local production from natural causes still in operation. Theoretically the case is possible, as any modern schoolboy knows that lakes without an outflow, and to a great extent the ocean itself, become saline from the continual concentration by evaporation of what we call sweet water. In the present case, however, the process with known data seems inadequate to the result. For a long time the

production of salt from the Sámbar lake has been on an extensive scale, and, as a source of salt, the lake dates from the mythical age. Myths are, no doubt, still a popular product of contemporary invention, and I cannot say whether historical documents throw any light upon the remote statistics of salt manufacture at Sámbar. But the facts in hand are sufficient, without appealing to ancient history; and I have seen no mention of any symptoms of failing in the supply. To accomplish so much within any reasonable time, with a catchment basin of only 2,000 square miles, would seem an impossible feat, and we must not forget that the formation of the lake itself, as already described, is apparently due to conditions that are, at least geologically, modern; the reign of sand in Rajputana may almost certainly be assigned as a result of the reign of quasi-civilized man, the Rajput and his compeers; for it can scarcely be doubted that it was once in the possession of the forest primeval.

In this connection it has been considered whether we might not call in the aid of some of the great northern rivers. It is well known that the Satlej formerly flowed far to the east of its present course, and it is geologically possible, or even probable, that the Jumna once upon a time flowed through Rajputana, west of the Arvali range.¹ The waste waters of those rivers, distributed widely by overflow and percolation, before the channels became diverted into lower ground, must have supplied to the soil a very large amount of saline matter, and under suitable conditions of evaporation and percolation this might be retained in those upper deposits. At the present day all the rainfall on the tract between the Jumna and the Satlej, where is now the 'divide' between the basins of the Indus and the Ganges, including the water of some considerable streams from the Siwalik hills, is wholly dissipated or absorbed within that area, there being little or no escape by surface drainage. It seems, however, that this aid cannot be called in at Sámbar, without almost inadmissible assumptions as to changes of level. There is certainly no room to suppose that the area under consideration has suffered from erosion; and at present the alluvial spill from the Himalaya on the north meets that of the Arvali from the south about Hissar, where we find the lowest ground in the cross-section of the Indo-Gangetic plains at their watershed. The elevation at Hissar is 700 feet, or nearly 500 feet lower than the Sámbar lake, 160 miles to the south.

There is yet another fact to be considered in this discussion. Without exception, so far as known, sweet water is obtainable from the alluvial deposits at lower levels than the saline water. I cannot say that this has been tried at any actual focus of salt production, but it is a fact of universal experience and practice in the region under notice and throughout the plains of north-west India to sink deep wells for fresh water, where the upper water stratum, as very often happens, is too salty for use. It might seem at first sight that this fact would at once put out of court a question we have had to leave undecided—whether there may not be recent marine deposits below the surface alluvium, which latter is everywhere proved by its fossil contents to be of fresh water origin; but it is abundantly proved that strata which must have been originally impregnated with

¹ See section, 'The Plains,' in the Gazetteer of the Punjab.

salt water become purged by the forced circulation of fresh-water underground from artesian pressure, so our fact is of small account in the argument for or against marine strata in the alluvium. It is, however, of great weight in the argument for the local and actually operative production of these deposits of salt; for it is almost beyond question that, as a common phenomenon in Upper India, the saline condition of the upper water stratum is due to the present operation of assignable conditions upon the surface and subsoil waters, whether rain water or as derived by percolation or irrigation from rivers and canals.

With such good evidence of a *vera causa* of salt production actually in operation, it should certainly be an object of continued observation and study whether such extreme cases of local concentration may not be brought within its action. It may, nevertheless, be well to point out what alternatives remain for those extreme cases. We can, I think, confidently assert that the Arvali formation (or rock series) is not the repository of rock-salt. These strata occur in many outliers far into the alluvium on the prolongation of the range, and always in the same condition of extreme disturbance. There is a strong probability that what is seen of them in natural outcrops throughout the range may be taken as fully representative of the whole series. Of the Vindhyan it may be asserted with even greater certitude that, so far as seen, they do not and never did contain rock-salt. It has even been conjectured that this formation, so far as known, is of fresh-water or subaerial origin; but this very conjecture might encourage the supposition of contemporary salt deposition in contiguous areas; while the undisturbed condition of these rocks would be in favour of the total concealment of any such deposits at a lower level than the actual outcrops. The area of covered ground here is quite extensive enough to conceal any such deposits of Vindhyan or of any subsequent age; and thus there remains the possibility of such a source for the salt of Sámbar and of other localities of apparently unlimited production.

RECORD OF GAS AND MUD ERUPTIONS ON THE ARAKAN COAST ON 12TH MARCH 1879
AND IN JUNE 1843.

The following reports by the local officers upon cases of eruptive action on the Arakan Coast are in continuation of those published in the Records for February 1879, Vol. XII, p. 70 :—

From LIEUT.-COLONEL W. W. PEMBERTON, Deputy Commissioner, Kyouk-Phyoo, to the Commissioner of Arakan, Akyab,—No. 41-14, dated 23rd June 1879.

Referring to your endorsement No. 451-222, General, dated 7th May last, on the subject of a recent volcanic eruption, I have the honour to state as follows :—

The Extra Assistant Commissioner of Cheduba was asked for a report on the subject, and in his reply he states that the eruption did not occur on the island of Cheduba. Some fishermen, who were out at sea-fishing at the time of the occurrence, told him that they had

observed the phenomenon and thought it occurred on the island of Ma-Gyee, while persons residing on that island said they had seen the illumination seawards north of the island. The Extra Assistant Commissioner then states that afterwards he was informed by a Burmese medical practitioner who happened to be at Sandoway on the night of the occurrence, that the explosion took place on a small island situated south of the Tha-dai-chyoungwa creek, in the Sandoway district, which statement was corroborated by some fishermen who came from Kha-Mongdoon, in the Sandoway district, and who happened to be fishing at sea at the time the phenomenon occurred.

Previous to the receipt of your letter under reply, I had heard of the occurrence, and sent to the Extra Assistant Commissioner of Cheduba for a report on the subject, but the outbreak of cholera in the town prevented him from making the enquiry for some time.

From MAJOR M. C. POOLE, Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—No. 3-49, dated 29th April 1879.

In continuation with the subject of your letter No. 95, dated 4th instant, I have the honour to mention that when at Htsengoung on the 12th March, I saw the sky brilliantly illuminated by an eruption of the volcano at Cheduba. Some of the Burmans with me going on shore and looking across the sea in the direction of Cheduba distinctly saw the flames. You have doubtless received further details from the Deputy Commissioner, Kyook-Phyoo.

From MAJOR M. C. POOLE, Officiating Deputy Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—No. 3-90, dated Sandoway, 31st July 1879.

In continuation of the subject contained in my letter No. 3-49, dated 29th April 1879, I have the honour to furnish all the additional information I have been enabled to collect regarding the volcanic phenomenon observed on the 12th March last. To my observation it appeared to emanate from some island lying north-west of Htsengoung; but not taking the bearings of the distant flames, I am unable to accurately define their position and joined in the hasty but not unnatural conclusion of the other spectators, that it was in the direction of the island, of Cheduba. I visited the village of Ka moun-doon on the 22nd instant, and there held conversation with some who had seen it; the day was beautifully clear, and from the slightly elevated shore, the southern extremity of the island of Ramree, the islands of Zagoo, Magree Kyoon, and Yey Kyoon, all stood out clear and distinct like a chart; in the distance could be distinguished the sharp serrated outline of hills in the island of Cheduba. The head-man of the village pointed out to me two sharp pinnacle-shaped rocks far out on the horizon, and known by the name of Kyouktabon which he said he was certain was the exact spot where the flames came from. These rocks lie south of Cheduba, and when viewed from Htsengoung, in a line with the north of that island and Yey Kyoon. This latter island was the scene of a similar occurrence in 1843, Captain Hopkinson's account of which I send a copy of. I am inclined to believe that most of these rocks and islands contain cavernous hollows in which petroleum or other gases are generated, and that they occasionally ignite and burst out. Several men who were at sea that night gave me different versions of what the aspect of the phenomenon was to them, varied of course by the different positions from which they saw it; I am of opinion, however, that the testimony of the headman at Ka-moun-doon is the most trustworthy, and my own opinion inclines to an endorsement of his view.

FROM CAPTAIN H. HOPKINSON, Officiating Senior Assistant Commissioner, Sandoway, to the Commissioner of Arakan, Akyab,—dated 25th November 1843.

Having, in compliance with the instructions contained in your letter to my address No. 838 of the 21st ultimo, proceeded to Rekeong or Flat Island for the purpose of making enquiries into the volcanic eruption which has recently been observed at the southern extremity of that island, I now beg to submit to you the result of my enquiries with all the information I have been able to collect in the matter.

2. Before I give the substance of the Thoogyee's deposition, I will endeavour to state what I saw myself, premising shortly that whatever island may have been formed by the submarine volcano has either sunk or perhaps, being merely composed of mud and loose volcanic fragments, has been washed away during the south-west monsoon, leaving no trace of its existence, and not even having disturbed the reef of rocks among which it is said to have arisen. I lament exceedingly my total ignorance of geological science which would most probably have led me to pass over much which was really valuable whilst I noted down objects of trivial importance, and which also prevents me from communicating any useful observation I might have made in such language as would be understood by a scientific person.

3. I arrived at Rugyoung on the third day after my departure from Sandoway, and immediately put myself in communication with the Thoogyee of the place, whose attendance to depose what he knew about the volcanic eruption and also to act as my guide to the site of their occurrence I procured for the following day. We started early in the morning and arrived near the small island in the vicinity of which the eruptions were remarked at 8 P.M. I was obliged to proceed for upwards of a mile from the island itself in the jolly-boat; reefs of sunken rocks running out in every direction preventing a nearer approach for the schooner, though otherwise the water was of a considerable depth, being from two to three fathoms within a boat's length of the little island itself. My office has not been furnished with a general chart of the province, and I do not know whether the island has been noted or not, but it may be easily identified, as I was careful to take its exact bearings to known points on the coast. I also made a rough survey of it by circumferenter and enclose a sketch thereof, showing the bearings, site of volcanic eruption, &c., &c. The rocks which formed the basis of the island were chiefly the common sandstone of Arakan, interspersed with large masses of rock, of which No. 1 of the specimens I had the honour to forward in the *Swallow* is a fragment. I could obtain no distinct traces of stratification on any part of the island, the action of the sea having broken up its surface into a confused mass of rocks. I have marked on the map the site of the volcanic eruption as given by the Soogree, but further than the mere direction goes, I do not think much dependence can be placed on its accuracy. The Soogree never visited the volcanic island; the eruption occurred during the height of the rains, when it is seldom clear for even a few hours, and the Soogree's nearest point of observation was, I should say, at least 4 miles distant. I should infer that the eruption must have been on a small scale, since from the testimony of the natives it appears that none of the numerous rocks near which they were observed have been altered in position, neither cast down nor upraised. I have marked on the sketch the situations from whence I took the different specimens before alluded to; the trap rock which I labelled hornblende was broken off a large rock about 12 feet square at top. The piece I have called felspar was from an adjacent rock, but smaller. I could only find the iron pyrites on the side nearest the volcano; there it was most plentiful, and I might have collected it by the maund; one specimen which I have called quartz is, I believe, limestone; its appearance at first misled me. On the sand mound I found large quantities of sponge of different kinds. I saw no coral on the island, nor any formation of it among the rocks, an unusual circumstance in Arakan. I looked for pumice, but did not find any.

4. The above is all that occurs to me to remark upon, and I shall now proceed to give the substance of the information gained from the Soogree: he states that in the month of Wageo or June, at about 8 o'clock in the morning, he observed the eruption for the first time, issuing apparently from between three rocks to the eastward of his village and about one hour's sail distance from it, to the south of Thee-byoo-gyoung-let, White Sand Island, the one in the sketch. The eruption was like fire of a bright red colour, and continued without intermission for three days, when it ceased, and deponent then observed that a small island has arisen from the sea; this island lasted for about a month, but he cannot say when it actually disappeared, for the weather was very boisterous during the whole time, and it was only by a calm supervening and the waves subsiding that he found the island had ceased to exist. The surface of the sea was as before, and not a rock was displaced; deponent did not visit the volcanic island, nor did any one in his circle, the fury of the waves prevented all approach to it. When he first visited the island nearest the site of the eruption, the only change he noticed was that some cocoanut trees had disappeared—probably been washed away—which were planted there about two years ago. During the time the eruption continued there was an unaccountable increase of water in the wells and tanks of his village; he also felt several slight shocks as of an earthquake during the time. The above, meagre as it is, is all the information I could obtain from the Soogree, but it was fully confirmed by the different inhabitants of Rekeoung whom I questioned on the subject.

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RECORDS
OF THE
GEOLOGICAL SURVEY OF INDIA.

Part 4.]

1880.

[November.

ON SOME PLEISTOCENE DEPOSITS OF THE NORTHERN PUNJAB, AND THE EVIDENCE
THEY AFFORD OF AN EXTREME CLIMATE DURING A PORTION OF THAT PERIOD,
by W. THEOBALD, Geological Survey of India.

The deposits to which I propose to direct attention in the following notes are those commonly called 'recent deposits,' and as such commonly neglected, though, if patiently interrogated, they are capable of affording a key to the solution of some interesting questions bearing on mundane physics of no very remote age. I allude, of course, to the much-vexed question of the extension, universal or otherwise, of glacial phenomena during a 'great ice age,' and particularly of the proofs, *pro* or *con*, for the existence of any such glacial phenomena in or near the plains of India, or at so low a level in the Northern Punjab as 2,000 or thereabouts. So long ago as 1867, Dr. Verchere recorded the presence of 'erratic' blocks in the Potwar at less than 2,000 feet altitude (*Jour., As. Soc., Bengal*, Vol. XXXVI, Part II, p. 113); but from the known liability of the Indus valley to cataclysmal inundations, consequent on the bursting of dams in its upper portion, the true bearings of these masses have never been properly appreciated, nor has any attempt been made to study the facts in detail or interpret the relation they bear to the general geological history of the district, and to postulate the conclusions we may legitimately deduce therefrom. The following papers may be beneficially consulted as bearing on the matters in question, and I cannot better preface my present remarks than by briefly reviewing what has been already written on the subject, and pointing out which statements require modifying, and wherein I differ from, or coincide with, the opinions of the writers I quote below—

Wynne, Records, Vol. X, pp. 107, 112, 122.

Theobald, „ „ X, p. 140.

„ „ „ X, p. 223.

Wynne, Memoirs, „ XIV, p. 116.

Lydekker, Records, Vol. XII, p. 29.

Wynne, „ „ XII, p. 114.

Blanford, Manual, pp. lxx, 372, 516, 586.

Medlicott, „ p. 668.

In the first paper Mr. Wynne describes the relations and characters of the post-tertiary and superficial deposits of the North-Western Punjab. These deposits he divides into an upper alluvium (elsewhere termed loëss), largely imbued in places with soda salts, and much cut up by ravines; and a lower division formed of "coarse pebble beds and sand or clay." These beds are described as not only filling the valleys, but covering large tracts of country, as, for example, in the neighbourhood of Rāwalpindi and elsewhere. They are described as rising to 3,000 feet above the sea; but this estimate may be indefinitely extended, if we take into consideration the homologous deposits which were being contemporaneously formed within the hills, and the high level gravels of the larger river valleys. Mr. Wynne's estimate, however, probably is meant only to include the deposits in the immediate vicinity of the outer hills of the Hazára district. The tertiary period may, in fact, be described as closing in a great subsiding movement of the Himalayan region, whereby the river valleys became filled up to the height of several hundred feet by coarse river deposits, and the whole country overspread by the gravels and the high-level alluvium which rests on them.

One remark of Mr. Wynne I believe to be erroneous. At page 124 we read, "With regard to the existence of a glacial period affecting the upper Punjab in very recent geological times, the only evidence the country seems to offer is in the occurrence of the formerly Indus-borne crystalline fragments at heights of some 2,000 feet above the present bed of the river. These would indicate either a very late elevation of the region traversed by the Indus, or, that when it ran in a channel so much higher, the hilly country to the northward may have been as much more lofty (or even higher still), and regions of perennial snow much nearer than they are at present." The above passage is couched in general terms, but I have reason for knowing that it particularly refers to the Chitapahár range south of Attock, and the word 'fragments,' which might be supposed to refer to 'erratics' really means only the rolled boulders of the Indus gravel. As, however, I felt very sceptical that the Indus, abandoning its deep and rocky gorge to the west of the Chitapahár hills, had ever really flowed here and there over the crest of that range, I addressed enquiries on this point to my colleague, and his reply, though intended, I think, to some extent as confirmatory of such an idea, really supports my own opinion on the subject to the contrary. In his reply, Mr. Wynne says:—"One swallow don't make a summer, one pebble would not make a gravel; so I can't declare there is any big deposit of Indus gravel on the Chita range, but all the same there are good large lumps of the Indus boulder deposits scattered about on the ranges of Bágh and Choi, at heights of 2,500 to 3,000 feet, too numerous to have been carried up by humans, who would not load themselves with two or three seers or more of such stones (gneiss, &c.) and carry them up some thousands of feet for the fun of the thing, or as prisoners do shot drill." Now I think these words of my colleague establish the fact that there is no deposit of gravel on the Chitapahár range, and that the inference of the former course of the Indus over its height rests on the occurrence of scattered boulders of Indus gravel, and in ignorance of any reason for supposing them to have been transported to the spot in question by human agency.

But a good and sufficient reason does exist for this latter explanation. It is

the habit in all this part of the Indus valley to collect boulders from the vicinity of the river and convey them away on carts or camels for the purpose of strengthening the mud-walls of the houses. Near the river the walls of many houses are mainly built of the larger boulders, whilst at a greater distance, the builders use these stones more sparingly, building them into the corners of the house only, where they protect the mud-walls from injury from passing cattle, &c. In many villages, too, a very old trait of patriarchal times may still be seen. Any very large smooth boulders or stones from Buddhist or other ruins, are brought up into the village, and either ranged under a tree or placed in some convenient spot for the use and delectation of the village headman, and 'grey beards,' precisely as we read in Homer, was the case in Pyle in the days of Neleus, three generations of articulate-speaking men before the fall of Troy. (Hom. Od., Book III, l. 404.)

Ἥμος δ' ἡριγένεια φάνη ῥοδοδάκτυλος ἠώς
 Ὠρνυτ' ἄρ' ἐξ εὐνῆφι Γερήνιος ἱππότα Νέστωρ
 Ἐκ δ' ἐλθὼν κατ' ἄρ' ἕζετ' ἐπὶ ξεστοῖσι λίθοισιν
 Οἱ οἱ ἔσαν προπάροιθε θυράων ὑψηλῶν
 Λευκοὶ, ἀποστίλβοντες ἀλείφατος οἷς ἐπὶ μὲν πρὶν
 Νηλεὺς ἴζεσκεν θέοφιν μῆστωρ ἀτάλαντος·
 Ἀλλ' ὁ μὲν ἤδη κηρὶ δαμεῖς Αἰδόςδε βεβήκει,
 Νέστωρ αὖ τότ' ἔφιξε Γερήνιος ἦρος Ἀχαιῶν,
 Σκῆπτρον ἔχων περὶ δ' υἱὲς ἀολλέες ἡγέρεθοντο.*

An even more probable explanation for the occurrence of Indus gravel at different spots on the Chitapahār range is the popular fashion of ornamenting graves in this part of the Punjab with smooth round stones, those of white quartz and variegated gneiss or schistose rock, being selected more commonly for this purpose. This practice may be noticed many miles from the river Indus, and proves that natural piety is as effective a stimulus for an unproductive expenditure of labour, as the harsh necessity of "shot drill;" and to this latter cause I attribute the presence of the Indus pebbles occasionally met with at considerable height on the Chitapahār hill. In many spots villages formerly existed, which are now abandoned in favour of the plains, owing to the security for life and property which the people now enjoy.

* 'Soon as Aurora, daughter of the Dawn,
 With rosy fingers, had unveiled the morn;
 From off his couch, Gerenian Nestor rose,
 And issuing forth, refreshed by night's repose,
 On polished stones, before his palace gate
 As Neleus used of yore, the monarch sate.
 White, smooth, and glittering in the sun they shone
 Unhewn, each block displayed a rustic throne;
 But Neleus passing to th' Elysian shade
 Wise Nestor reigned and Pyle's sceptre sway'd,
 Whilst numerous sons around, obeisance made.'

I have myself crossed the Chitapahár range twice, and have both times carefully sought for evidence of the Indus having formerly flowed over it, but without success, and I believe that river has never deviated from the deep gorge whereby it now crosses this barrier. The highest alluvial deposit which can be referred to the river Indus in this quarter, is a homogeneous clay, which is seen in places on the flanks of the range south of Choi,¹ rising to a height (roughly guessed) of between 300 to 400 feet above the present bed of the river.

This clay may possibly be of lacustrine origin if the Chuch Hazára plain and neighbourhood were ever occupied by a lake prior to the lowering of the Indus bed to its present depth. Anyhow I should say 400 feet was the highest level on the Chitapahár range above the present Indus bed, at which any distinct Indus alluvium can be made out. So much for positive indications.

But there is one very powerful negative argument against the idea of the Indus ever having hereabouts flowed at the height indicated by Mr. Wynne.

Above the limits at which the clay in question occurs, the hills are formed of vertical beds of limestone, cut up or furrowed by deep, almost cavernous, fissures, forming a deeply *serrated* surface, which would have acted as the most efficient pebble trap that could be imagined, and into which any pebbles must have been washed, without the possibility of their being subsequently cleared out again. Yet not a single pebble or boulder of any sort can be seen in any of these rifts, the conclusion being therefore irresistible that no wash of gravel has ever taken place over them.

The next papers to notice are two by myself in Records, Vol. X, pages 140 and 223. In the former I describe an alluvial deposit in the Potwar with numerous species of living shells, and a peculiar silt near Jand, possibly indicative of glacial conditions at the time it was being deposited. Perhaps the most important fact, however, was the occurrence of a large 'erratic' "over 20 feet in girth, *resting on alluvium at a high level*, eight and a half miles from Pindigheb and eleven miles from Taman" (l. c., p. 142). This is a valuable indication of the relative age of the glacial conditions presumed to have obtained in the district, and the older alluvium; the instance here quoted not admitting of any doubt as to the fact of the 'erratic' reposing on a thick bed of alluvium. My other paper refers to certain distinctions that should be drawn between 'erratics' of the pleistocene period and the 'erratics,' which in the Salt-range are embedded in strata of mesozoic and palæozoic age, and which are as distinct in their lithological aspect, as they are from the Indus erratics by their geological age. In his Memoir on the Salt-range (Vol. XIV) in a note to page 117, Mr. Wynne thus correctly, as I believe, alludes to the 'erratics' of the Indus valley:—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of." That is, than by ice agency. Two of these are described in Records X, p. 124, as having a girth

¹ Choi is not on the Atlas map. It is, however, a little under 3 miles from the mouth of the Haro on the south bank of that river, and is a halting stage (with a 'sarai') on the road from Attock to Khushálgarh.

of 50 feet by 6 to 8 feet high, and 48 feet 6 inches by 12 feet 6 inches high; the former a granitoid rock, the last of basalt.

I now pass to the consideration of a clearly-written and valuable paper by Mr. Lydekker in Records XII, p. 15, in which the glacial question is treated at some length. Among general conclusions my colleague affirms that in Kashmir 6,500 feet is about the lowest level at which "undoubted evidence of former glacier action" exists. This, I think, may be true, as I have myself been struck with the remarkable absence of such evidence in the valley, though I never questioned the existence of such evidence at much lower levels in the outer hills. The cause of this, should the statement not require modification, is I regard an interesting object for future investigation. Mr. Lydekker differs also from Prof. Leith Adams in his failing to recognise any proofs of a glacial origin for the Báramula gravels, and in this I agree with my colleague. At page 30 (*l. c.*) Mr. Lydekker records his dissent from Colonel Godwin-Austen's opinion that certain granitoid blocks in the Jhelum valley below Báramula have been brought to their present position by ice action. Here I dissent from my colleague, and consider that Colonel Godwin-Austen has rightly estimated the mode of transport of these blocks in question. In support of his view my colleague goes at some length into a description of the Jhelum valley, which, being clear in language, and conveying completely my own views, I shall here quote *in extenso*. That my colleague has arrived at a different conclusion to myself, I attribute solely to the accident that he has not seen such a 'key section,' as I may term it, as I was fortunate enough to discover during last season's work in the valley of the Nainsukh, above Gurhi Habibula:—

"At Rámpur the alluvial formation contains gneissic blocks, some of which are as much as 15 feet in diameter; the whole formation is at least one hundred feet in thickness on the left bank of the river. The included blocks are all more or less rounded and water-worn, while the matrix in which they are embedded is here but little stratified. As we descend the river, the blocks of gneiss continue to decrease in size till we come upon the sharp bend in the river below Rámpur; here a fresh stream of gneiss blocks has come down a tributary stream from the second gneiss mass in the Káj-Nág range: some of these blocks have a long diameter of 20 feet.

"Still continuing our survey down the river, we find the gneiss blocks again becoming smaller and smaller, and half way to Uri the alluvial deposit is seen to be most distinctly stratified. All the gneiss boulders have their long axes inclined up the stream and towards the river bed at an angle of about 30°; so that one of the flat sides is opposed to the flow of the stream, as we find to be the case in any deposit of modern river pebbles. The summit of the alluvial formation is level, forming high-level plateaux on either side of the river. At Uri we find a similar plateau, some 200 feet in thickness, formed of the red Sirmur rocks of the neighbouring hills. The pebbles in this deposit are rounded and have the same relative position in regard to the stream as the gneiss blocks higher up. A few small gneiss blocks are found in the Uri deposit."

Now all this I fully accept as a correct description of the Jhelum terrace gravels and boulder deposits, for I regard it would be as one-sided in me to

either fail or refuse to recognise the agency of water in their arrangement as I hold it to be in any opponents who fail to recognise the proofs of glacial agency concurrently present in the same area.

I do not point to well-rounded boulders embedded in a stratified deposit, with their long axes arranged with reference to the direction of the river, as proof of glacial agency; but I do point to streams of blocks not so rounded, but sub-angular and piled on one another, with little or no intervening matter, in a fashion suggestive of moraine rather than river transport. It is true the rock of which the largest blocks consist rounds off by surface exfoliation under atmospheric action; but the streams of sub-angular blocks, to which I allude, have no nearer resemblance to the water-worn boulders described by my colleague than accrues from their consisting of the same identical rock. As an instance in point I may mention, on the right bank of the Jhelum the stream of blocks which is seen to descend the Kathai stream just below the Fort of Kathai, and is buried in the surface of the high level plateau before reaching the Jhelum. These blocks are scattered about, *sometimes isolated on the surface of the alluvial plateau whereon they rest, in other places ranged in clusters or piled against each other with little or no intervening matter; and they are all more or less sub-angular, and have none of the appearance of having been washed down the valley or by the stream.* Granting, for argument's sake, that a great debacle might have washed them down, it would not have arranged them in a long thin line, heading up the valley; in a word, their arrangement is decidedly suggestive of moraine action as distinguished from fluvial.

Mr. Lydekker adds (*l.c.*, p. 31):—"It will be gathered from the above observations, that the whole of the gneiss blocks in the Jhelum valley have followed the course of tributary mountain streams, have not been carried across intervening ridges, and are embedded in an aqueous formation." To this passage I can give my cordial assent, if I may interpolate after the word 'in', the words 'and on,' which in my opinion furnish the clue to the discrepancy of opinion between my colleague and myself. The rounded blocks to which my colleague points as conclusive of fluvial agency may be, and no doubt are, embedded *in* river deposits; the sub-angular ones on which I no less confidently rely as proving moraine agency are, I believe, always found resting, not *in*, but *on*, the above river deposits.

There is one paragraph with which I cannot agree:—"It will be gathered from the above observations that the Jhelum is now a denuding, and not a depositing, river, as it was when these alluvial formations were laid down; from which we may probably infer that great changes of level have taken place since the period of these deposits, *which may have afforded greater facilities at certain times for the movements of the blocks.*" This is far from clear. The 'change in level,' which converted the Jhelum from an excavating stream employed in deepening its bed into a depositing one, which it must have been when it refilled its valley with alluvial deposits 200 or 300 feet thick, was one of subsidence, whereby the *gradient* of the Jhelum valley, both the main channel and all its tributaries, was lowered,—the proximate cause, of course, of the deposition of the above beds: *cæteris paribus*, therefore, this change could neither

physically nor climatally have afforded greater facilities for the transport of large blocks than previously existed; rather the contrary.

In his "further notes, &c." (Record XII., p. 114), Mr. Wynne divides the pleistocene deposits of the Northern Punjab into an upper, middle, and lower sub-division, characterizing them respectively as "Northern detrital drift," "Alluvium and river drift," "Post tertiary valley or lake deposits."

It may be questioned how far the middle and lower of these sub-divisions are separable or dissimilar; but the great merit of this division is that it distinctly recognises the relative position of the 'glacial deposits' and the older alluvium, and shows how nearly on the verge of discovering the true significance of this fact Mr. Wynne was.

Mr. Wynne is, however, careful to let it be known that he disclaims glacial agency in the distribution of his 'Northern detrital drift', not only by introducing the somewhat superfluous adjective 'detrital', but by the definition he gives at page 132 (*l. c.*):—"Northern drift. I use this term instead of the more simple one "erratic drift," which would appear to convey to some Indian geologists a closer connexion with glacial geology than is necessary to the purpose." This disclaimer suffices to show how nearly Mr. Wynne missed recognising the essential merit of his own classification. Especially when read in connexion with what follows:—"By Northern drift, then, is here meant that influx of travelled masses which has followed the course of the Indus from the north and been distributed over large spaces of the Ráwalpindi plateau, to a distance (I am informed by Mr. Theobald) of 25 miles from the river. These blocks are easily recognisable, all along the upper Indus as far as I went, to be the same as those further down its course. *They often rest on the terraces, and some of them are of very large size.*" Mark how very nearly discovering the truth Mr. Wynne must here have been (how he 'burned,' as children say at 'blind man's buff'), could he only have recognised the significance of their not occurring in the terraced gravels though scattered about on them! Considering, too, that Mr. Wynne gives the girth of one of these blocks near Torbela as 109 feet, his disclaimer of glacial agency on its transport seems to me to savour of caution overmuch! It would, indeed, seem to be an afterthought, as in his *Geology of the Salt Range*, at page 117, Mr. Wynne thus expresses himself of these very blocks:—"In other parts of the country, too, along the left bank of the Indus south of Attock, the foreign erratic blocks are too numerous and too large to be accounted for satisfactorily in any other way that I know of"—that is, than by ice; and it is, I think, to be regretted that Mr. Wynne should have been led to abandon this sound view, and substitute for it the disclaimer of glacial agency in his later paper, quoted above.

At the end of the paper in the *Records* (XII, p. 132), Mr. Wynne notices a detached mass of limestone 127 paces in girth, which may possibly be an 'erratic' slipped down from Sirban mountain, aided possibly by ice before the intervening ravine was cut, or, as I would suggest, when it might have been sheeted over by ice; and Mr. Wynne records the discovery by myself of glacial striæ on a block of quartzite below Torbela. I mention this to express my belief that the striæ in question are not glacial, as I once supposed they might be; but

what could have produced straight, but not parallel, scratches on a hard corneous quartzite, I cannot say. They may be glacial, but their varying direction makes this very doubtful.

To revert now to my own observations during the past season. I may commence by saying that a re-examination of the ground near Jand failed to verify the occurrence of 'erratic' blocks in the peculiar silt of that neighbourhood. The occurrence of 'erratic' blocks in this silt rests on two presumed instances recorded in my paper (Records X, p. 142) of such blocks being seen reposing *in situ* and partly embedded in the silt; but from the conditions of the case, such an observation requires corroboration, and hitherto my search for a section displaying such blocks embedded in the silt has not been rewarded with success; and the glacial character of the deposit may therefore be still considered as unsettled. That this silt is a lacustrine deposit, is, I think, more than probable, and that it is really the homologue of the coarse alluvial accumulations near Ráwalpindi, when the lower part of the Sohán valley and the adjoining region along the Indus, with the Chuch Hazára plain, constituted a lake through which the Indus flowed, and which owed its origin in part perhaps to that subsidence of the whole area to which the thick alluvial deposits in the Indus valley and its tributaries bear testimony. If my suggestion is correct, that this silt is the exact homologue of the clays and gravels to the east and north, it at once explains why no erratics are found embedded in it, though more or less widely dispersed over the area covered by it, since I shall presently show that the glacial conditions whereby the erratics in question became distributed, *supervened* on (that is, after) the deposition of the gravels in question. At page 516 of the Manual, Mr. Blandford suggests the idea of lacustrine conditions as contributing to the dispersal of these blocks, with the alternative suggestion of a "*variation in the course of the Indus, and to the reversed flow of its tributaries in great floods.*" I shall endeavour to show that each of these suggestions has its share in producing the phenomena under review. The lineal arrangement of these 'erratics' in the Potwár,—one line following the general direction of the Sohán valley, whilst a parallel train of erratics passed near Jand (Rec. X., page 142), could only have originated in two ways,—either through 'moraines' descending to the Indus trough, or through floating masses of ice sweeping up the tributary valleys during a reversed flow of the streams produced by floods. And the result would not be interfered with, supposing the area adjoining the river to have been temporarily covered by a lake, as the reversed flow of the streams falling into the lake, during the rise in its waters resulting from Indus floods, would suffice to establish a direct current, mainly coinciding with the old river channels, through the body of still water of the lake at large and constituting *water lanes*, along which the erratic blocks and floating ice could be carried, and to which the linear arrangement of the blocks now seen would be due. If, however, there was no lake, the 'reversed' flow of flood would produce this lineal arrangement of erratics, as a matter of course; but the presence of a lake would, I think, no less permit of a similar distribution of the blocks, and would fully account for their presence in the situations they are found to occupy, that is, on the top of the alluvium, as near Pindigheb, for example, and Taman.

Leaving the vicinity of Jand, which may be regarded as somewhere near the centre of the supposed lake, and proceeding north, we find an instructive section of these valley deposits near Pari, on the Nára river (3 miles east-south-east from Shádipur, on the right bank of the Indus) and about 15 miles from Jand. Approaching the Indus from the south-east, along the road leading to Pari and Shádipur, we see in front of us a long stretch of rising ground, more or less parallel with the river and decreasing in height away from the banks. The edge of this line of rising ground is very rugged and broken up by denudation, and the Nára river below Pari gives a clear section of the beds, showing that the rising ground in question is simply a belt of coarse beds, whose maximum thickness is attained in the immediate vicinity of the river, and which thins out away from its channel, owing to the coarser material being at once deposited, whilst the finer sediment only is conveyed to more distant parts of the valley. The bed of the Indus is here cut deeply in Siwalik sandstones, dipping mostly at high angles. On the edge of these beds rests a thick alluvial deposit, divisible into a lower or conglomeratic portion, and an upper division of clays in which the conglomeratic element is wholly subordinate—the united thickness of both divisions along the river not falling short of 80 or 100 feet, though how much has been removed by surface denudation, it is impossible to say. The lower conglomerate is very coarse and heterogeneously composed, the largest boulders in it being of nummulitic limestone, commonly 3 or 4 feet in girth; and often sub-angular, the ingredients being evidently derived from the Chitapahár range only a few miles distant to the north. This deposit is clearly a coarse river gravel, but although very large blocks occur in it, I did not notice decisive proofs of glacial conditions—that is, any monster blocks of the Hazára gneiss actually in it. In the valley of the Nára river, however, one mile east of Shádipur, I noticed two huge ‘erratics’ not far apart, one of Hazara gneiss 50 feet in girth, and one of nummulitic limestone 60 feet in girth; but although these might have been derived (from the position they were in) from the coarse bottom bed above described, they might equally have been let down into the stream bed from a higher position by mere denudation, and this view is supported by other considerations I shall soon adduce. All about Pari, too, large craggy masses of limestone are scattered, which may be doubtfully referred either to this coarse bed or to ice flotation at a later period; and their distance from the river, and their being out of the direct line of its floods properly so viewed, render the latter supposition, I think, the preferable one. Above this coarse bottom bed occurs a group of clays of equal thickness, or greater perhaps, away from the immediate vicinity of the river. This clay in places contains a little kankar, and forms the general surface of the country hereabouts; and on its surface genuine erratics are here and there seen of the Hazára gneiss, which, as I believe, can have been only so brought by ice flotation; and if we regard the basal conglomerates as local deposits, resulting from the proximity of the Indus gorge (below Níláb Gásh) and the Chitapahár range, the homology between the Jand silt and the ordinary valley alluvium is clearly seen, both resting on the denuded sandstones, wherein the river has now deeply sunk, and both supporting genuine ‘erratic’ blocks of a later period.

Leaving now the Potwár, and crossing the Chitapahár range, we descend into the valley of the Hurroh (which joins the Indus at the rectangular bend that river makes to the west), at Nilat, where the old royal road from Pesháwar to Hindustan used to cross, and both the Haripur and Chuch plains offer some points of great interest in connection with their recent deposits and the physical changes of surface they reveal.

The Haripur plain is bounded on all sides except to the south-west by hills, and is composed of a deep alluvial deposit, the older rocks not usually appearing, away from the hills which bound the valley. South of the old cantonments of Haripur, the whole of the drainage of the valley is conveyed into the Hurroh river; whilst that to the north finds its way into the Dorh, which, after being joined by the Siran, flows into the Indus above Torbela, past the northern extremity of Gandgarh mountain, which is interposed between that river and the Haripur plain. No erratics occur in any part of the Haripur plain, and the valley of the Hurroh is wholly free from them till within a mile or less of the spot where the Pesháwar trunk road crosses the stream. Down to this point the valley may be said to be sheltered by the mass of Gandgarh; but directly the lower ridges south of Gandgarh are passed (going west), 'erratics' of Hazára gneiss, or the Indus 'erratics,' as they may be called, appear in some force, and from the spot where the road crosses continue down the valley of Hurroh as far as its junction with the Indus at Barotha. These 'erratics,' as I have stated, have not descended the Hurroh valley, but have cut abruptly into it from the Indus, below the sheltering barrier of Gandgarh, or, in other words, the former course of the Indus coincided with the present course of the Hurroh, west and south of that mountain. This will be rendered clear by a glance at the accompanying sketch map, whereon is marked the course of these Indus 'erratics' and their distribution in this neighbourhood; and it will be at once apparent that at no remote period the Kabul river joined the Indus—not, as now, at Attock, but close to Barotha, some 9 miles to the south. The whole of the country between the trunk road on the north and the Hurroh on the south, consists of rolling 'downs' of river alluvium, mostly sandy, with here and there a sprinkling of Indus gravel and boulders, and scattered 'erratics'—these last being specially numerous along the course of the Hurroh, as the annexed map will show.¹ Many of these erratics are of large size, 50 feet in girth or more, though of course the majority are smaller. They consist of Hazára gneiss or of limestone, which last rock has not travelled so far as the other. The sketches here given (see Plate) of one near Dakner and of another near Jand, by Mr. Wynne, will give a good idea of the general appearance of these blocks—those of limestone or of any crystalline schist being, from the nature of the rock, usually more jagged and angular than those of gneiss, which is so wont to 'flake off' at the surface.

No one, I think, who considers that the above 'erratics' (granite) have travelled from the most distant parts of Hazára, and are now seen reposing on a sandy plain, will entertain serious doubts as to their truly 'erratic' character, or that they have been conveyed by ice flotation to the positions they now occupy.

¹ See also Wynne's map, Records X, Part 3.

GEOLOGICAL SURVEY OF INDIA

Theobald.

Records Vol. XIII.



Erratics of Gneiss near Dakner 4 Miles S. S. E. of Attock



J. Schauer.

Erratics of Gneiss near Dakner 4 Miles S. S. E. of Attock

Mr. Wynne also writes as follows (Records X, p. 124):—"On one of the river terraces of the Indus gorge, between Pari and Báhtar, I measured an 'erratic' mass of unfossiliferous limestone 9 feet high and 74 feet in girth, which may have belonged to any of the neighbouring limestones, from the lower nummulitic downwards, and seems to be as truly an erratic block as any of the others." No doubt this block had not travelled far, but it is interesting to find such a mass on an old river terrace, when the full significance is realised of such blocks occurring on the old gravels, but not in them, as would seem to have been always assumed as being the case, as a matter of course, by the opponents of glacial theories.

No less interesting, as proving the altered surface conditions now prevailing, are the indications afforded by the lower part of the Dohr valley, where it is joined by the Siran. Leaving Haripur by the Torbela road, which descends sensibly, and continues nearly parallel to the course of the Dohr, we come in sight, at about 4 miles, of what seems a low ridge stretching right across the valley and connecting the hills across the Dohr with the Gandgarh range of hills. A little to the left of this seeming ridge, and perched on the foot of the Gandgarh hills, is the village of Dari; and away to the right is Barukot. Approaching nearer, we find that the seeming ridge is breached right in front of us by the Dohr, after being joined by a small stream from the south, when it flows on and joins the Siran close to the village of Tapli. The road along the bank of the Dohr here affords an excellent section of the coarse boulder deposits which seem to constitute the ridge in question. On the Gandgarh flanks, round which the road winds, the deposit consists of coarse gravel and boulder conglomerates, with a good many Indus erratics strewn about the hill side and lying in the bed of the stream. One of these near Tapli was measured by Mr. Wynne (Records, XII, p. 132) and found to be 109 feet in girth, and others of about half that size are pretty frequent lower down. None of these have descended the Dohr, and at first sight the impression was a very strong one that the seeming bank on which Barukot stands, littered over as it is with 'erratics,' was a moraine which had descended the Siran valley and been breached by the Dohr prior to its effecting a junction with the former river. An examination of the ground about Barukot, however, totally dispelled this view and revealed a very curious and anomalous condition of things. The ridge in question was found to be a remnant of the same old alluvium constituting the Haripur plain, and cut into a tongue by the Siran on one side of it and the Dohr on the other. This spit, or tongue, is thickly covered with Indus boulder gravel and some erratics; but not a single erratic or boulder encroaches on or is found in the Haripur plain, which is here below it in level; and I do not think any of this gravel is discernible over 100 yards beyond its sharply-defined boundary at the village of Dari, or south of the Dohr, which ran under the Barukot ridge.

In the valley of the Siran, not a boulder or erratic is to be seen, and the surprising inference is unavoidable that the capping of boulder gravels and erratics has been washed over the Haripur alluvium from the Indus itself. At first sight it would seem as if these erratics and boulder gravel or drift must have ascended the course of the joint Dohr and Siran valley, but a glance at the map and the space covered by these 'erratics' will show that supposition is not necessary. But

the remarkable thing is, that if the Indus current brought this gravel over the top of what now form the Barukot ridge, it did not pass bodily round Gandgarh hills and flow through the plains east of Gandgarh.

The accumulation of 'erratics' rafted by ice, up a backwater of a tributary during a flood in the main river, could be easily understood; but not so a thick deposit of boulder gravel, unless on the supposition that the well-rounded character of the boulders is no bar to their being a veritable glacial deposit also. And this conclusion is, I think, the only one admissible. A strong current alone (if we dismiss the idea of ice flotation) could have accumulated the coarse cap of boulder gravel and clays here seen, between Dari and Barukot; but if the Indus flowed as far as Dari in full current, it must have flowed further towards Haripur; but this it unquestionably never did, and the conclusion therefore is that this deposit is one formed by floating ice charged with clay and boulders, which accumulated in the 'cul de sac' of the Dohr mouth and deposited its burden on melting all over the area submerged by the Indus flood water. The reason why the Indus did not flow further into the Haripur plain is of course that the plain was then higher than now, and barred the further advance of the flood waters laden with 'erratics' in that direction. As I have remarked, the boundary of this coarse boulder deposit is very sharp and defined, and this belt of gravel has served to check denudation over the area covered by it, while the undefended alluvium of the Haripur plain has been greatly lowered by the scour of the Dohr and its feeders, the result being the scarped gravel-capped ridge on which Barukot stands. Parts of this deposit have a certain resemblance to the *Talchir boulder bed*, in consisting of a compact clay in which boulders are disseminated, as may be seen in the cuttings on the Torbela road, though the bulk of the deposit is a coarse stratified boulder gravel.

The following localities for 'erratics' may be specified. From Barukot to Torbela along the course of the Dohr, and on the left bank of the Indus for some miles above Torbela, some of these gneiss erratics are over 100 feet in girth. Near Attock small erratics, as well as rounded boulders, are freely scattered about to a level of from 300 (or perhaps 400) feet, or thereabouts, above the present bed of the river. South of Háji Shah a gneiss 'erratic,' some 20 feet in girth, is lying in a field, and some smaller ones near it. One mile north-east of Campbellpur is a gneiss 'erratic' 30 feet in girth, and in the low ground near Campbellpur, an enormous number of 'erratics' from 20 to 30 up to near 100 feet in girth. The largest of these are limestone, but some of the smaller ones are of gneiss. South-east of Campbellpur, near the village of Boliwála, a little outside, seemingly, the limits of the Indus bed, or Haro (Hurroh) channel as it now is, a few 'erratics' are seen 12 feet or more in girth; and these blocks were probably stranded there during floods. At $1\frac{1}{2}$ mile east-south-east from Boliwála is a granite 'erratic' in a field by itself, with 'cup marks' on the top.

The whole country in this direction, towards Kala-ka-serai, is an old high level alluvium, co-extensive with the Indus alluvium of the lower Haro (Hurroh) valley, but no erratics save those near Boliwála on its edge were noticed in it. Some 3 miles north-east of Choi, on the road from Campbellpur, a huge and jagged erratic of quartzose gneiss occurs. It has spontaneously broken up into

several pieces, but must when whole have measured some 60 feet in girth. In a word, the whole country is dotted with these erratics from the point where the Peshawar road crosses the Haro, to the mouth of that river at Barotha, and thence to Dakner in the Attock road.

Across the Indus, in a north-west direction, stretches the Yusufzai plain, the broad open valley of the lower portion of the Kabul river. This plain consists of a thick deposit of alluvium laid down by the Kabul river and its tributaries, and may be partly at least of lacustrine origin. I made one traverse across it from Nowshera to Hoti Murdán. Opposite Nowshera is a low range, over which the road is carried. To the right the range sinks down and is covered over by alluvium. Resting on this alluvium, were a good many large limestone blocks, which seemed to have travelled from the neighbouring range, rafted as I imagine by ice. A little west of the road, on the slopes of the range, I noticed a large block of limestone "perched" on three smaller blocks on the alluvium. These blocks had none of the appearance of being artificially arranged, and if not, this must be considered a truly '*perched*' block. None of these blocks exceed 6 or 8 feet in diameter, and they are all derived from the ridge to the west of the road. I noticed no erratics along the line of road from Attock to Peshawar, and it is pretty certain the Indus 'erratics' never invaded the Yusufzai plain. This I at first thought strange, till I discovered that at the period of their transport, the Indus ran (as explained) far south of its present course and east of Attock to Barotha, which may help to account for no erratics being seen north of Attock, though no doubt the valley of the Kabul river will be found to have its own proper 'erratics' of the period when search is made for them.

The Pakli plain, or valley north of Mánshahra, and the Ughi plain to the north-west, both present the same general feature; they are both surrounded by hills, the former being traversed by the Siran river, the latter by the Ughi river, falling into the Indus near Derband. In the Pakli valley the alluvium of the Siran river is some 300 feet thick or thereabouts, of which an excellent section is seen on the road from Mánshahra to either Ughi or Shinkíári. No 'erratics' are seen in the valley gravels, which are simply ordinary river gravels and clays interstratified; but large boulders, which I regard as erratics, are occasionally seen, strewn over the surface. In the open part of the valley these blocks are exceptional; but a few miles from Shinkíári, where the Siran debouches from the hills, and all up the Siran valley, below and above Shinkíári, erratic blocks are very numerous at all levels resting on the surface of the ground.

I have not examined the Ughi plain in detail, but at the foot of the Susalgali pass leading from Mansahra to Ughi, and a few miles from that place, I noticed a few granite blocks resting on the alluvium, precisely as noticed near Shinkíári.

It is, however, in the valley of the Nainsukh or Kanhar river that the clearest sections are seen demonstrating the relations of the 'erratics' of the glacial period to the older alluvial deposits.

The Nainsukh falls into the Jhelum opposite Rara, and at Gurhi-Habibulla on the direct road from Mánshahra to Muzafarábád, is a muddy brawling glacier stream, spanned by a handsome suspension bridge. In the bed of the stream

are numerous 'erratics,' and I determined to trace them to their source, though I hardly anticipated so clear and decisive a result as rewarded my efforts.

The valley of the Nainsukh or Kanhar river, draining the Kaghán valley on the north, is very narrow with a very great fall, and bounded on either side by ranges of hills with peaks from 8,000 to 15,000 feet or more. On nearing Garhi Habibulla from Mánahra enormous 'fans' are seen descending from the range across the river (to the east) to the stream. On the west bank, however, the road from Garhi to Kaghán lies along the bed of the stream, and is skirted in many places for miles by a steep cliff of old river gravels, through which the brawling river has cut its present bed. This cliff varies from 80 to 100 feet or more in height, and the thickness of the gravels, or old alluvial deposits, of the Kanhar river may be 150 or 200 feet or more, which is neither easy on a cursory visit, nor material to determine. In this cliff every pebble is clearly exposed, and the striking fact was soon established beyond all question, that no 'erratics' existed in this deposit from top to bottom. Yet, they were plentiful enough in the bed of the stream, from 15 to 60 feet or more in girth.

Where, then, did they come from?

About Garhi, the gravel of this old alluvium is not very coarse, that is, it is a gravel in which boulders of one foot in diameter are rare and conspicuous for their size, contrasted with the bulk of the materials around them. Ascending the stream, however, the deposit increases in coarseness gradually, till near Byssia, boulders of from 1 to 10 feet in diameter have become pretty numerous, but no erratics or boulders of a larger size. The section of the deposit is clear, and the fact indisputable. A mile below Byssia, the road winds round an almost overhanging cliff of these gravels. Here an occasional boulder of 3 feet in diameter may be detected, though such are rare; whilst in the river bed beneath huge 'erratics' are plentiful, and a little way higher up numbers occur, two of which were over 70 feet in girth. The largest 'erratics' in the river bed are of the usual Hazára gneiss; whereas gneiss is not prominent in the terrace gravels, and only in small boulders, the larger blocks in these beds consisting of limestone, hard schists, or trap rocks. It, therefore, became perfectly clear, even before reaching Byssia, that no erratics were being brought down by *any* agency during the period these old gravels were being laid down.

This deduction, which is beyond challenge, is the key to the glacial phenomena of the entire sub-Himalayan region.

Byssia is built on a low terrace of coarse gravel, as described above; but it is not more than a third as high as the terrace near Garhi. On the opposite bank of the river, however, a part of the old alluvial terrace is seen of the usual height, so it is clear that *some agency* has operated to reduce the height of that portion on which Byssia stands. Close to the village some scattered 'erratics' are seen, and at the village graves, a line of erratics commences and extends thence right up the valley. The annexed sketch (see map) will illustrate the general feature of the ground. The erratic blocks are of the ordinary character of the Hazára gneiss erratics; and it would seem to be the continuation of this line, engulfed in the river, which I noticed above as yielding blocks 70 feet in girth.

The origin of this stream of 'erratics' is not far to seek. Ascending the valley above Byssia, the village of Shahwal is soon reached, standing on the further bank of a small stream. Down this stream has descended what those who please may call a 'fan,' but what I term a 'moraine,' disintegrated perhaps by subsequent stream action, but which consists of an enormous stream of granite blocks from the range behind, up, say, to 40 feet or more in girth. This stream unites with a similar one which has descended the main valley, and is just an old lateral moraine. A little way below this a small streamlet of blocks has forced its way down a narrow valley,—I may almost say cascaded down it,—and joining the larger lateral moraine of Shahwal has helped to swell the stream of blocks all tending towards Byssia. The little valley alluded to is barely 50 yards broad with steep V sides, and yet several of the blocks piled all on top of each other are from 40 to 70 feet in girth and completely jam the gorge. The fall of this gorge is steep, and I doubt if it ever contains a couple of feet of water, and that must be often broken up into foam, cascading over these rocky masses, the arrangement of which is shown in the outline section, fig. 2 (see map).

In bringing forward this section, however, I claim to be understood intelligently, and not to be confronted by inapplicable syllogisms of the well-known V order of argument of the antiglacialists. Whoever, indeed, looks here for ice marks on the rocks will be disappointed; nor can the obvious history of the gorge lead to any other anticipation. The gorge originally gave passage to a small glacier, as no other means I consider adequate to the transport of the rocky masses found in it. The base of the glacier no doubt was of the usual shape, and at a much higher level than the present bed of the V-shaped gorge. On the disappearance of the glacier, stream action commenced, and, aided by the scour of the sharp granite detritus, soon effaced the old valley and cut down the present V-shaped channel into which, *pari passu*, the 'erratic' blocks subsided. To imagine that such a piddling stream as could ever have found its way down here, brought down these huge blocks, is simply absurd. The argument might be adduced for the large stream under Shahwal, but not here.

The constitution, however, of the old river gravels disproves the idea that stream action which produced them had any influence in bringing down the 'erratics.' The material of which the 'erratics' consist, existed then, as now, close at hand in the adjoining ranges, but the *power* to move them was wanting, till the supervention of glacial conditions during a later period. It would be mere repetition to describe similar cases all up the valley, the 'erratics' everywhere reposing on the river gravels and being obviously referrible to subsequent ice action and not to river transport.

The consideration of the above facts affords a key, in my opinion, for reconciling the opposing views held, regarding the share played by ice in the formation of these recent deposits. The presence of huge 'erratics' strewn over the outer hills is appealed to by men like myself, supporters of glacial views, as a proof of the reality of such agency, and is opposed by other observers on the ground that such blocks are embedded in deposits of palpably fluvial origin, but *till now* it has never been shown that both advocates are in a measure right, though in reality the erratic blocks merely rest on and are not really embedded, save

superficially, in the river deposits. To quote an example: Near Ríási, on the Chináb, an enormous limestone 'erratic' was pointed out by me to my colleagues, Messrs. Medlicott and Lydekker, in proof of glacial conditions having necessarily been involved in its transport, but as it *rested on* a thick deposit of river gravels, my argument was held to be discredited. In these cases, *as in all others that I have seen*, this 'erratic' block rested on the river deposits, but the true significance of this fact was not then fully comprehended by any of us, and was looked on as fortuitous, in place of being the normal position of these blocks with reference to the old river gravels.

Considering then, as I do, that the distinct relation of a newer glacial deposit, consisting mainly of 'erratic' blocks, to an older fluvial deposit, as established beyond controversy by the sections seen in the Kanhar river, and the consequent extension of an isothermal line compatible with the existence of glaciers, to so low a level as between 2,000 and 3,000 feet in the Northern Punjab, I would here add a few words on the various objections which have been adduced against the possibility of such a condition of things elsewhere.

In my paper on the ancient glaciers of the Kángra district (Records VII, p. 86), I endeavoured to show that the 'erratics' originally described by Mr. Medlicott as 'glacial debris of the Dhauladhár' (Memoirs, III, Part 2, p. 155) were really due to moraine transport; but I did not then comprehend the true key of their seeming anomalous relation to fluvial deposits wherever they are seen to rest. I did not then apprehend that they only rested on such deposits and were not enveloped in them. But I *did comprehend and claim to have distinctly asserted that they were of moraine origin, and, what is more, that there should be no possible misapprehension* (though in this I was vastly mistaken), I divided the area into three vertical zones or areas, naming each respectively pre-glacial, glacial, and post-glacial. I quote my own words (*l. c.* p. 93). "The Kángra district may be ideally divided into three vertical areas or zones:

Firstly, a pre-glacial area embracing the whole country, which contributed from peak to plain to the *genesis*, and development of the glaciers under consideration; speaking roundly and without any measured data to check the estimate, the above zone or area embraces all ground higher than from 250 to 300 feet above the mean level of the present streams.

Secondly, a glacial area proper, embracing the entire area either occupied or excavated by the glaciers, which may be approximately fixed as commencing at the bottom of the above division and terminating below, at a level of about 150 feet more or less above the mean level of the present streams.

Thirdly, a post-glacial area, embracing the whole of the ground below the basal limit of the last division and the result of aerial denudation subsequent to the cessation of glacial conditions."

The precise figures used are, of course, open to correction, but no possible exegesis can render the above words *clearer than they are*, as they stand, and yet Mr. J. F. Campbell, F.G.S., with my paper in his hand, actually potters about, looking for glacial markings within my *post-glacial area*, and finding none, pronounced my theory discredited (see Journal, Asiatic Society of Bengal,

Vol. XLVI, Part II, 1877, Campbell on Himalayan glaciation). I shall not discuss Mr. Campbell's brochure at length, simply because a man who professes to refute the views of another, which his every word proves him not to have comprehended, cannot be profitably argued with, but some [of Mr. Campbell's arguments, being of a general nature and the joint property and stock-in-trade of all anti-glacial geologists, may be here noticed. It may be here mentioned that as Mr. Campbell has not realised the conditions which I believe really obtained, many of the arguments adduced are really and truly beside the question; but "n'importe."]

Arguments why glaciers never descended, as ascribed by me, to within 2,000 or 3,000 feet of the sea in Northern India:—

I.—The course of these suppositive glaciers lies along V-shaped valleys, which indicate aqueous, not glacial, erosion.

Undoubtedly, as the remarks previously made show, the glaciers descended on top of an enormous accumulation of gravels filling up the old valleys of a V shape. These gravels were only partly cut down and cleared away by the glaciers; and partly to this, and partly to the post-glacial action of streams, the contours of the ground are all of the V kind. Argument No. I is consequently worthless.

II.—No glacial markings are found on rocks *in situ*, as must have been the case had each river bed given passage to a glacier, as asserted.

To this I remark, that search for such marks seems generally to have been made by Mr. Campbell in places where, if my theory is correct, no glacier ever descended, that is, in contact with the present rock surface; and that the ordinary roads leading up our large river valleys lie, as a matter of fact, below the level, where ice action would have left its mark. Then, again, so much of the ground in question is made up of rock unfitted for, or incapable of, retaining 'ice markings;' and when the rock is fitted, it forms crags above the paths now used, accessible to few living things, save the wild goat and his natural enemy, the human hunter. This argument is therefore no better than the last.

III.—Absence of striated blocks within the area asserted to have been traversed by glaciers.

To this I reply that the rock which has furnished the largest and most numerous 'erratics' (granitoid gneiss) is wholly unfitted for the retention of any

¹ Mr. Campbell's observation was very far from being so preposterous as Mr. Theobald would make out. Notwithstanding the definitions quoted above—a general meaning for which (and it would be ridiculous to attach a rigorous meaning to such definitions, where the conditions necessarily admit of exceptions) was sufficiently obvious, in the prevailing erosion of the river gorges below the level of the old gravels—it was a perfectly fair, or even inevitable, inference that any rock-surface supporting the old gravels was one on which, according to Mr. Theobald, a glacier had travelled. Mr. Campbell found such a surface freshly exposed, but without any trace of the markings required by such conditions. There might remain a dispute about the identity of the gravels at that spot, but this would altogether change the venue of the case. It would seem that Mr. Theobald did not at the time comprehend his own brochure otherwise than Mr. Campbell; for in a subsequent notice (Records X, p. 140) of the opinion that had been passed upon the supposed glaciers of the Kāngra valley, he makes no allusion to the rejoinder which he now (as suggested by his recent observations) urges with such ultra ferocious vigour—a triumphant style which by no means helps to impart the conviction it ostensibly implies.—H. B. M.

such marks; and also that the deposits, whereon *these erratics rest*, being of fluvial origin, have naturally been searched in vain for such evidence; and lastly (whatever may be the reason therefor), in India, scratched blocks are so rare as almost to be exceptional in the vicinity of existing glaciers. The absence or rarity of 'scratched blocks' at low levels is merely, therefore, a negative argument, which, if of any force, might be used to disprove the existence of glaciers, where they are now actually to be met with. Argument No. III therefore is as little cogent as its predecessors.

IV.—Water power is sufficient to account for the transport of the blocks termed by me 'erratics' and referred by me to either floating ice or 'moraines.'

This is an argument which anti-glacialists never weary of producing, in season and out of season, and requires therefore some consideration. As the Kāngra 'erratics' range up to 150 feet in girth, and many of them of very large size stand well out in the plains, away from the hills and in cultivated ground, I have no belief in such a vehicle for such blocks. How the case might be in a river bed is another matter; but standing, as many of these erratics do, in open ground, the idea is not tenable for an instant.¹

Mr. Campbell remarks: "I am quite certain that the Kāngra erratics are large 'pebbles' washed out of the 'cads'² by heavy floods." Now, if these erratics were met with *only* in the 'cads' (khuds) or more numerous in the khuds, than out of them, Mr. Campbell's argument would have a colourable basis; but the reverse is the case, and the largest blocks are found in spots where it is impossible they could have been washed into out of any possible khud.

To descend, however, from the general to the particular. Let us examine the case of how Indian rivers do deal with masses, such as Kāngra 'erratics.'

In my Kāngra paper I say: "At Sujānpur, the moraine of the Sujānpur glacier is seen pushed right across the present channel of the Beas, at a *much higher level* than that of the present stream, which has made a clean and deep cut through it; yet, though the 'erratic' blocks scattered round the travellers' bungalow at Sujānpur and all over the truncated end of the moraine on the opposite side of the river are of a large size, not a trace of one can be seen in the river bed beneath."

This disappearance of the 'erratics' in the bed of the stream may be accounted for in three ways. There is, first, the 'rush of water' theory of the anti-glacialists, and, doubtless, if a piddling stream could have brought these blocks as far as the banks of the Beas, the bigger river could have easily moved them on; in which case we should expect to find them congregated in a lump or bar, at the first spot where the reduced velocity of the river outside the hills deprived it of the

¹ The fallacy of assuming that the surface on which these blocks now lie is that on which they were deposited, has been already indicated (Jour. As. Soc., Bengal, XLVI, Pt. II, p. 13).—H. B. M.

² I am indebted to Mr. Medlicott for kindly pointing out to me that the word 'cad' which I had (in my ignorance) supposed to be a local term, current in the Highlands of Scotland, and pure Gaelic for gravels, was merely a novel mode of spelling the common Indian word 'khud' = a steep valley.

necessary power required to carry the block onwards; but no such accumulation is seen, and hence it is very doubtful if the river ever acted in this manner. Secondly, the blocks, after being engulfed in the main channel, may be supposed to have been destroyed by wear and tear and the impact of rolling masses during floods. Such a process, no doubt, disposes of a vast bulk of materials in every stream; but it is a process probably more active in mountain torrents with a steeper fall, but less actual body of water than the Beas. Thirdly, there is the scouring action, which during floods undermines big obstacles to the current, and eventually entombs them in the grave thus produced, levelling the gravel flush over the spot where they have disappeared; and this I believe to be the case in the Beas, and the true explanation of the paucity of 'erratics' in its channel.

To consider now the case of a river whose velocity largely exceeds that of the Beas at Sujánpur. The Jhelum below Uri fulfils this condition, as the stream is there in many spots a 'race,' and the bed of the river is full, moreover, of these very erratics, derived from the lofty peaks of the Káj Nág adjoining. What water can do in a stream bed with such 'erratics' we here see. The effect of the rapid stream is to clear away all gravel and smaller boulders, leaving the larger masses packed against each other, with great cavernous interspaces between. Over these masses of rock, the waters cascade in sheets of foam, or force their way in hissing jets between or beneath them; but the rocky masses themselves are immovably packed by the very force and agency of that element which some would regard as capable under such circumstances of sweeping them away. Not a bit of it—occasionally a blasted pine, whirling down stream, gets swept between the blocks, and by its leverage wrenches them apart; but this is a passing incident, and its effect, so far as any onward and progressive movement of the blocks is concerned, is inappreciable.

These two instances of the Beas and Jhelum illustrate the power possessed by water under the ordinary operations of nature to move masses like the sub-Himalayan erratics; but the necessity of weighing the argument is almost dispensed with from the now established fact (presuming the Kángra and Hazára deposits to be homologous) that the erratics do not occur embedded in the old river gravels, but simply resting on them.

How, too, I ask, on the supposition advocated by Mr. Campbell, that the 'erratics,' as I consider them, are merely masses transported down a 'fan' by stream action—how, I ask, comes it, that they have crossed over the Beas from north to south, as shown in my map above Sujánpur. It is impossible that the materials swept into a river down a 'fan' should cross its channel and be found on the opposite bank. With the old glaciers the case was different. They coincided generally only with the present valleys, but not with the existing river beds; and hence, as in the case of the 'erratics' on the south bank of the Beas at Sujánpur, their moraines were breached by the rivers which succeeded them. The same argument and the same latitude will not apply to any supposed rivers, as agents in producing this arrangement of 'erratics;' as, supposing the Beas (as is a simple supposition, quite possible) to have formerly held the more southern course, which I suppose the glacier here did, and to have run south of where the 'erratics' in question now occur, yet it is impossible to suppose that the river

can have cut its way back north into its present course without removing, in so doing, the 'erratics' which stand in a position which would, under such circumstances, have been its channel for a certain period. The contour of the ground, too, is opposed to the idea of the river having ever flowed, at the spot, more to the south, so that the 'fan' theory of 'erratic' transport wholly breaks down.

The following notes, penned so far back as 1871, may be here quoted, as the views then advocated are strongly corroborated by the foregoing results of last season.

"The interest which attaches to any well-defined traces of former glacial conditions, away from the immediate vicinity of the main Himalayan ranges, induces me to bring forward such an instance (as I believe it to be) on the flank of Jogi Tillah, the well-known hill near Jhelum, and which must, if substantiated, offer considerable support to the view of a former more extensive glaciation in India than is generally supposed, and not dependent on any present local features, orographical or hypsometrical.

"Jogi Tillah, which rises somewhat abruptly from the plains, is situated 16 miles west-south-west from Jhelum, and may be regarded as the most easterly termination of the Salt-range, though severed from it by some complicated faulting and the channel of the Búnhar river. The mountain itself is a wedge of rock forming an epitome of the Salt-range strata, and displaying at base the devonian salt marl on the one hand, whilst on its opposite slope a thin belt of nummulitic limestone dips at a steep angle beneath the extended newer tertiaries which form the great Potowar plateau. As the dip of the beds is to the north-west, the scarp of the hill faces the south-east, and below the scarp, the hill side falls rapidly away over a talus of fragmentary blocks deeply excavated by ravines which furrow the newer tertiary beds at its base. Viewed from a distance, the profile of the outer hills immediately beyond the scarp of the mountain is peculiar, the outline being that of a long, flat hill, with a slope outward of less than 10," though what is seen is really the profile of one of many long ridges, separated by narrow valleys, deeply excavated in the soft tertiary sands and clays. So far there is nothing peculiar, nor are any (at least prominent) traces of glacial action met with either to the east or west of the hill, or over the flat Potowar plateau stretching away for miles to the north of it. For a narrow space, however, of about 3 miles west of Hún, over a belt of ground corresponding with the loftiest point of the mountain, the whole surface is more or less thickly covered with blocks, irregular and sub-angular, of the rocks forming the mass of the hill and presenting all the appearance of having formed part of an enormous moraine, or group of moraines, which swept down with a grand curve a little west of Hamula, and thence on to within a similar distance of Hún, both villages standing just outside of the great stream of fragments. On the top of the ridges, now some 200 feet or more above the present streams, these fragments are thickly packed, but they are also seen strewed over the sides of the hill and choking up the beds of the streams. The general relations and arrangement of these blocks are

nowhere better seen than on the road from Hún to Hamula, and just where the road reaches the small stream west of the latter village, the whole country betrays signs of being littered over with moraine debris, though all, if I mistake not, subsided through their gravity and the gradually washing away of the soft tertiary beds whereon they once rested, and not actually *in situ*. This is clearly seen by tracing the blocks up the steep slope of the hill to their undisturbed place at the top, the top being the long sloping ridge, seen in all distant views of the ground as gradually sloping from the base of the scarped side of the mountain.

"On the top, then, only, of these ridges (no doubt once an extended and continuous plateau) the undisturbed moraine materials are seen, but beyond, on the lower ground, and on the sides of the hills, the materials are distributed, under the influence of ordinary denudation and gravity.

"The blocks which form this great flood of stones are irregular in shape and sub-angular, of no very great size, 2 feet in diameter, perhaps being a fair mean, though some larger ones are interspersed here and there. The largest remarked by me was barely 8 feet in length, and was split into three pieces, where it lay, most probably, by the action of frost, to which may be attributed the absence of any large fragments. The majority of blocks consisted of the magnesian limestone, or some of the sandstones found in the hill; but the red sandstone, overlying the salt marl, though not absent, was scarce, and the few specimens seen were much decayed from the joint action of saline infiltration and the consequent disintegration of the stone through the action of moisture and frost.

"That these stones all descended from the scarp of Jogi Tillah is clear, but *how* is the question. The ground covered by these blocks may be roughly taken as some 3 miles in breadth opposite the highest peaks of Jogi Tillah, whilst the flood of stones extends over 3 miles or more from the highest peaks. Now the horizontal catchment area opposite the highest scarp is not appreciably greater than on an equal breadth opposite the less elevated portions of the mountain, so that had mere streams been the motive power, we should have to account for a local debacle of stones for which no adequate explanation through local stream action was available; whereas in the case of a glacier, it is clear that the magnitude of the associated moraine would bear a more or less close ratio to the altitude of the rocky face from which the glacier originated, just such a relation, in fact, as these scattered masses display with relation to the highest point of the mountain.

"Three miles may seem a distance not too great for these blocks to have travelled during the countless centuries during which the streams have been lowering their channels from the old high level at which they once ran—the old glacier level in fact; but such a supposition leaves out of sight two points: first, that though such small streams as descend from Jogi Tillah are capable of a very powerful erosive action on the soft beds through which they run, their direct transporting power forwards as regards large subangular masses of stone is almost *nil*; and, secondly, that the great bulk of debris, which I term a 'moraine,' is certainly transported, and that a clear distinction can be observed between the high level bulk of the deposit, which may be regarded as the material

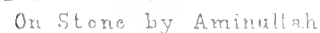
as left, *in situ*, by the cessation of the transporting cause, and the subsidiary effect of stream cutting which has since been going on, allowing the lapse from the higher level of the "moraine" matters by simple gravity into the newer and ever-deepening channels. There is thus a "consensus" of arguments all tending to support a glacial origin for the blocks in question.

"There is the general appearance so suggestive of a moraine in the arrangement of the coarse materials, and the marked and definite sweep they assume west of Hún and Hamula. Then there is the marked relation of this band of debris to the highest part of the hill, which might of course call for no remark if it was confined to a mere talus along the base of the mountain, but is very significant when it is found stretching outward at a high level in a manner hardly compatible with mere fluvial agency, and there is the difficulty of admitting the power of streams to produce such a result under the peculiar physical and surface conditions of the neighbourhood. Finally, it can hardly be questioned that Jogi Tillah lies well within the isothermal limits of former glacier extension, since I have shown that at the period in question that line embraced the southern flanks of the outer hills down to the plains west of the Jumna."

The above extract from my notes is given with trivial verbal alterations, precisely as it was written in 1871; indeed there is no call for any alteration. Both Mr. Medlicott and Mr. Lydekker accompanied me over the ground, and they were much struck with the appearances which I refer to glacial conditions, though I believe their verdict at the time was one of 'not proven.' It was then certainly more bold to adduce such a cause than it would be now, after so convincing a demonstration of glacial agency at low levels has been made out; but I had previously discovered symptoms of glacial influences to the east, which, if not conclusive *per se*, had their proper weight in determining my own conclusions. I will mention a few—not that I insist in every instance that they are absolutely indications of glacial agency, but that such agency seems the most probable explanation thereof, and, with a view to direct future observers to these obscure features, that their true bearing may be better elucidated. In the northern part of the Jhelum district, in the vicinity of the Jhelum river, a noteworthy feature in the landscape is the presence of flat, high level plateaux. These are but thinly covered by surface alluvium, and are not portions of old lake beds, but consist of sandstones with various dip planed down flat in a manner which makes it difficult to refer such to the result of wandering stream action. These flat plateaux are sometimes slightly inclined, and the most natural explanation of this particular surface configuration is 'ice action.' It is a feature I have nowhere seen noticed or alluded to by previous writers, and I consider it one which merits further study.

The occurrence in the valleys of moraine materials, disposed as I have described in the Kunhar valley, I shall not here allude to at length, as such cases are rarely so clear as seen there, and I may have an opportunity of re-examining some spots where such deposits are in force, as in some tributaries of the Chináb. I will, however, mention one case of a transported block which I think can be due to none save glacial agency. It is a limestone block lying on the stream, 12 miles south-west from Ríási, on the Chináb, between the villages Bardol and





INDUS BASIN ATTACK.

Karkeli. This block of limestone has been derived from the limestone range to the north near Poni; but the entire drainage area within which it lies is composed of Siwalik sandstones, and it must have crossed the present watershed before the excavation of the existing valley. The Chináb here debouches from its rocky gorge into the more open valley below Riási, and flows through a very thick coarse boulder deposit, 4 miles broad and 8 miles in length, measured along the river, which deposits tail off, and rapidly diminish as we recede from the river, and are in my opinion largely composed of the re-arranged glacial materials which must have filled the Chináb valley at no remote date, and I refer the limestone block near Bardol to the same agency and period as that to which I attribute the erratic block previously mentioned as lying on the top of a thick river gravel near Riási. At Bardol, however, the block in question has subsided into the valley by the removal, by denudation, of the looser materials whereon it rested; whereas near Riási the other block is still resting in nearly its original position, on the undisturbed gravel at a high level above the river. No doubt numerous similar cases occur; but this one may be particularised, as there is no ambiguity regarding its position and relations.

USEFUL MINERALS OF THE ARVALI REGION by C. A. HACKET, *Geological Survey of India.*

Although the Arvali region does not abound in mineral wealth, still it contains several extensive mines from which, in bygone times, large quantities of copper and lead ores have been extracted, and a number of small pits or burrows where ores in small quantities were found.

None of these mines were worked deeper than a few feet below the water level on account of the difficulty of raising the water. In some cases, however, when the mine is situated on a hill, an adit level has been driven into the hill to drain the workings and cut the veins at a lower level in hope of finding richer deposits; but I believe, both in the case at Ajmere and Daribo, these hopes were not realised.

All these mines, with the exception of those worked for iron, are now abandoned, and the workings filled with water or fallen together, and so little is now seen that it is impossible to form an opinion of their value.

The ore occurs either in small discontinuous veins or thinly disseminated through the rocks. In no case is there anything like a continuous vein or lode exposed.

The following is a list of the minerals, and the localities where found:—

COPPER.						Atlas sheet.
						No.
Singháua	...	...	} Shaikbawáti, Jeypore	...	...	49
Khetri	...	...		...	...
Daribo	...	...	South of Kho, Ulwar	...	...	50
„ in the ridge 1½ miles to the west	...	...	...	...	...	50
Bhangarh	...	...	Ulwar	...	...	50

							Atlas sheet No.
Kushalgarh	...	...	Ulwar	...	...	...	50
Baghani	...	...	Do.	...	...	...	50
Partabgarh	...	...	Do.	...	...	...	50
West of Nabaro	...	...	} Near Sainthal, Jeypore	...	...	...	50
West of Udbala	...	...		...	...	...	50
South-east of Garh	...	...	} Lalsot hills, Jeypore	...	...	...	50
Lalsot	...	...		...	...	...	50
Babai ...	...	...	Shaikhawáti, Jeypore	...	...	...	50
Nithahar	...	...	Bhurlpore	...	...	...	50
Datunda	...	...	Boondee	...	...	...	34 S.E.
Rewara	...	...	Near Gangapur, Oodeypore	...	...	...	34 S.W.
Ajmere	...	...	Near the Jail	...	...	...	34 N.E.
Tasing	...	...	Mandan hills, Ulwar	...	...	...	50
Jasingpura	...	...	Near the railway, Ulwar	...	...	...	50
Gugra	...	...	4 miles north-north-east of Ajmere	...	...	...	34 N.E.
Rájgarh	...	...	10 miles south of Ajmere	...	...	...	34 N.E.
Rajauri	...	...	Near the above	...	...	...	34 N.E.

GALENA.

Táragarh hill	...	...	Ajmere	...	...	...	34 N.E.
Ganespura	...	...	30 miles south of Ajmere	...	...	...	34 N.E.
Indawás	...	...	} Thana Ghazi, Ulwar	...	...	...	50
Gudha	...	...		...	...	...	50

IRON.

Bhangarh	...	...	} Ulwar	...	...	...	50
Rájgarh	...	...		...	...	...	50
Karwar	...	...	Hindaun, Jeypore	...	...	...	34 N.E.
Ajmere	...	...	Near the Jail	...	...	...	35 S.E.
Gangár	...	...	Oodeypore	...	...	...	34 S.E.
Bhaironpura	...	...	Boondee	...	...	...	34 S.E.

NICKEL AND COBALT.

Bhangarh	Ulwar	50
Babai	Shaikhawáti, Jeypore	50

ZINC.

Jáwar	Oodeypore.	50
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RUTILE.

Motidongri ridge	Near Ulwar	50
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PLUMBAGO.

Sohna	Gurgaon	49
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GOLD.

Sohna	Gurgaon	49
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KAOLIN.

						Atlas sheet No.
Kusumpura	South of Delhi	49
Bachára	Ulwar hills	50

GARNETS.

Sarwár	...	...	20 miles south-east of Nusseerabad	...	...	34 N.E.
Rájmahál	Jeypore	34 N.E.
Meja	Oodeypore	34 S.E.

ROCK CRYSTAL.

Aurangpur	15 miles south of Delhi	49
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MARBLE.

Makrana	Jodhpore	33 S.E.
Jheri	Ulwar	50
Raialo (Raiwala)	Jeypore	50
Sarangwa	6 miles west of Desuri, Oodeypore	34 S.W.

STEATITE.

Móra, Bhandári	About 12 miles north of Hindaun, Jeypore	...	34 S.W.
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The most extensive of these mines are those of Khetri and Singhana in Shaikhawáti, Daribo in Ulwar, and the lead mine at the base of the Táragarh hill near Ajmere. The rest are, comparatively, very small.

Copper.—That the old workings, both at Khetri and Singhana, were very extensive, and the quantity of ore raised considerable, is shown from the large and numerous heaps of slags resulting from the smelting of the copper ore. The hill on which the Singhana fort is built is formed, in a great part, of these slags.

The abandonment of the mines is attributed to the partial failure of the ore in depth and to the increased cost of working, and as the Jeypore Durbar would not reduce the royalties, the miners abandoned the mines and left the country. At present a few men make a living by picking out some stones of ore left in the old workings; and a number of people are engaged in the manufacture of Lila (blue vitriol), Pitkhera (alum), and Kasis (copperas).

The Khetri mines are situated a short distance north of the fort near the crest of a ridge of slates about 500 feet above the level of the plain. The mine is entered by several shafts of considerable depth, and which lead down to a gallery, said to be upwards of 2 miles in length. The direction of the level, as pointed out to me, appeared to be parallel to the strike of the slates. The ore now brought up from the old workings is copper pyrites; it occurs in small strings, and disseminated through the slates.

The Singhara mine is about 6 miles north of Khetri. It is entered by a wide gallery driven into a ridge of quartzite, in the same direction as the strike of the rocks, and near the top of the ridge several hundred feet above the level of the plain. This gallery is, in places, 40 to 50 yards wide and of a considerable

height. Its course into the hill is very irregular; the descent for the first hundred yards is slight; beyond this the gradient becomes steep, not less than 60° ; judging from the extent of the excavation, a rich pocket of ore must have been met with. At this point three separate galleries extend into the hill somewhat oblique to each other.

Beyond the extent of the excavations very little is to be seen in these galleries, as hardly a spec of copper has been left by the old miners, and the ends are choked up by fallen debris or filled with water.

My guide through the mine had formerly leased it; and he acknowledged that the mine was abandoned from the failure of the ore in depth. But it is possible that in continuing the level southwards other pockets of ore would be met with. The mine is in a line with the Khetri mine, and it seems probable that many pockets of ore would be found if the intervening ground were explored.

Some time since, report says about a hundred years ago, the roof of the gallery for about 100 yards from the mouth fell in, and a vertical face of the quartzites has been left standing in which numerous thin strings and nests of ore are exposed.

I was told that this was the mode of occurrence of the ore in the mine. In the bottom of the gallery only a few traces of copper are to be seen, thus showing that these strings or small veins did not extend, at this place, to any depth through the quartzites.

Considerable quantities of blue vitriol (sulphate of copper), alum, and copperas (sulphate of iron), are now manufactured both at Khetri and Singhana from the decomposed slates and the refuse of the mines. The slates are steeped in water, which is afterwards evaporated in large iron vessels, when the blue vitriol is first crystallized out, afterwards the alum and lastly the copperas. Mr. Mallet found traces of nickel and cobalt in all three of these substances.

The blue vitriol is sold for	...	...	Rs. 14 per maund.
„ alum	„	...	„ 4 „
„ copperas	„	...	Re. 1 „

The Babai workings are in a line with these two mines and on the same band of slates, about 8 miles south of Khetri. The workings consist of a few pits sunk in the hill side. A little copper is found disseminated through the slates, but I believe the pits are principally worked for Saita, or ore of cobalt, of which mention will presently be made.

The next mine of importance is that of Daribo, near Kho, in the Ulwar territory. The mine is situated in a sharp anticlinal bend in slates and quartzites. An adit level is driven into the hill through the slates in a southerly direction parallel to the strike of the rocks. I could see no trace of a lode; the ore appears to be irregularly disseminated through the black slates, a few specs and stains only being seen in the quartzites. Where richer nests of the ore were met with, the miners have extended their workings a short distance above and below the level. The miners declare that a rich nest of ore occurs in a pit sunk below the level near its southern extremity, but it had to be abandoned on account of the water.

The present drift was, I believe, begun under the instructions of Captain Impey, formerly Political Agent at Ulwar, to drain the pits sunk by the natives in the hill side.

The copper occurs in the form of copper pyrites, mixed with arsenical iron. The mine is now nearly abandoned and but little ore is to be seen. I had some difficulty in finding a bit the size of a hazel nut.

Blue vitriol, alum, and copperas are manufactured at the mine.

I found traces of copper in some slates on the same geological horizon in the ridge a short distance west of Daribo.

The Bhargarh workings consist of two or three small pits now fallen together. The workings of Kushalgarh, Baghani, and Partágarh have been abandoned for many years. The natives say that at the two latter places the workings were very extensive, and that the mine fell together suddenly, burying a large number of men.

A few small pits have been sunk in the quartzites west of Nabaro and west of Udhala, both near Sainthal in the Jeypore territory, from which a little copper ore may have been extracted, as the debris on the surface is stained with copper.

Near Lalsot, in Jeypore territory, a small hole has been made in the face of the scarp, and the stones about are stained with copper. At Garh, about 15 miles north-east of the above, a pit has been sunk to the depth of about 20 or 30 feet. There were traces of copper round the mouth of the pit. In both these cases, although the rocks surrounding the pits were bare and unbroken, I could find no trace of a vein or even of copper in any direction a yard from the pit's mouth.

At Nithahar, in the Bhurtpore territory, a short level has been driven into the hill and a small quantity of copper raised.

A small pit has been sunk in the quartzites about 2 miles east of Datunda in the Boondée territory. The stones are stained with copper, but I should not think sufficient was raised to pay the costs of the pit.

At Rewara, near Gangapur, in Oodeypore, a number of small pits are sunk in the schists in a north and south line for nearly a mile in length. These pits have all fallen together, or are filled with water. The copper appears to have been smelted on the spot, but judging from the small quantity of slags, no very large amount of ore was raised.

I observed traces of copper in the old iron workings near the jail at Ajmere, also at Tasing in the Mandan hills, and at Jasingpura near the railway, both in the Ulwar territory.

Captain C. J. Dixon, in a report dated 8th May 1835, published in the *Journal of the Asiatic Society*, Vol. IV, page 583, mentions the occurrence of copper ore at three localities near Ajmere, *viz.*, at Gúgra, 4 miles north-north-east of Ajmere, Rájgarh, 12 miles south-south-west of this, and at Rájauri, 10 miles south of Ajmere.

Galena.—The only lead mine of any importance occurs at the base of the Tárargarh hill near Ajmere. Formerly these mines produced large quantities of lead, although there appears to be some discrepancy in the accounts as to the amount. Thus, Captain C. J. Dixon, in a paper ("Some account of the lead

mines of Ajmere") published in 1831 in *Gleanings in Science*, Vol., III, page 111, states: "The produce of the mines has hitherto been very limited. The annual quantity of metal smelted averages about 850 cwt.;" while it is stated in the *Ajmere Gazetteer*: "Mr. Wilder, the first Superintendent of Ajmere (in 1818), took the mines under direct management, and they produced annually from 10,000 to 12,000 maunds of lead, which was sold at Rs. 11 per maund.

"The Ajmere magazine was the chief customer, and on its ceasing to take metal in 1846 the mines were closed."

The mines consist of a number of pits sunk in a line several hundred yards long, extending from the hill to near the walls of the city. The ore occurs in a number of small roughly parallel veins running through a quartzite in nearly the same direction as the strike of the rocks. An adit level has also been driven into the hill, at a lower level, to drain these pits.

A small quantity of lead ore has been extracted from a pit sunk near Ganespura, about 30 miles south of Ajmere.

Some old lead workings occur at Indawas and Gudha, in Thana Ghazi, in the Ulwar territory. The former consists in a long open cutting from 20 to 30 feet deep, from which, apparently, a considerable quantity of ore has been raised. The workings are now filled with water. At the latter place a small pocket of ore was recently discovered, but which on being worked was found to die out in every direction.

Iron and Manganese.—Iron ore occurs in several localities, and some of the mines have been and are still extensively worked.

The mines of Bhangarh in Ulwar still produce large quantities of ore. These are now the only source of iron for the numerous furnaces in the Ulwar territory. The ore is a mixture of limonite, magnetite, and oxide of manganese, containing 59·67 per cent. of iron and 12·7 of manganese (Mr. Mallet's analysis).

The old and extensive mines near Rajgarh in Ulwar are not now worked.

Large quantities of a superior iron ore have been raised at Karwar, near Hindaun, but the workings are now abandoned, probably from the scarcity of fuel.

There are some old iron workings near the jail at Ajmere, but the produce must have been very small.

Iron ore is now worked to some extent near Gangar, in Oodeypore, and near Bhairampura, in Boondee.

Nickel and Cobalt.—Traces of nickel have been found in some of the iron ores from Bhangarh, but the pit from which the ore was taken has fallen together.

An ore of cobalt called *saita* (or *selitu*) is found in the slate hills near Babai in fine strings, and sparsely disseminated through the slates, with pyrrhotite (magnetic iron pyrites) and copper pyrites. It is described in mineralogical works as Syepoorite (probably a mistake for Jyepoorite), sulphuret of cobalt (sulphur 36·36, cobalt 64·64). The ore is used for colouring enamels, bangles, &c., of a blue colour.

Zinc.—Large quantities are said to have been obtained from Jawar, in Oodeypore, but as yet my examination of the country has not extended so far south as this.

Rutile.—Rutile (titanic acid) exists in small quantities in some little quartz veins in the Motidongri ridge a short distance south of Ulwar.

Plumbago.—At the back of the town of Sohna, in the Gurgaon district, a thin irregular band of schists occurs in quartzites. From these schists some specimens of plumbago have been taken. There are no traces of any excavations ever having been made, except a very small pit, which could not have been many feet deep. Anything that I could see was exceedingly poor, and hardly deserved the name of plumbago, and I doubt if any much richer was ever taken from this locality. A specimen sent to me by the Deputy Commissioner was as poor as those I picked up.

Gold.—When examining these schists, the Sohna Lumbadár told me that after every rains small quantities of gold were extracted from the sand, mud, &c., of the little water-courses at the bottom of the hill. I questioned the Chumárs of the town, who told me that it was true that they made a few rupees every year in this way, and that the heavier the rains, the larger the amount of gold. Last year, for instance (1877), as the rains were so slight, they did not get any, or did not think it worth while looking for.

The only rocks exposed in the gully are the quartzites and the schists. As it is not probable that the gold would be washed out of the hard quartzites, it must, I presume, come from the schists.

Kaolin.—The kaolin mines are situated at Kussoompur, and a short distance to south, in the Delhi hills, a few miles north of the Kutub Minár. There is only one mine now worked, and that, unfortunately, had not yet been opened for the season, so that I could only judge from surface appearances.

There are few small pits sunk in a hollow entirely surrounded by quartzites. The stuff brought out of the pits resembles, in every particular, components of the numerous granite dykes in the Arvali series, only the felspar in this case is decomposed. The plates of mica and crystals of quartz are mixed up with the kaolin in exactly the same way as they are with the white felspar in the granite veins.

This decomposed rock is thrown into water, when the mica and quartz are separated from the kaolin, and the latter made into small cakes and used for white-washing purposes, and as fire-clay.

Another kaolin mine occurs at Buchara, near the Lota river, in the Ulwar hills. There are numerous granitic veins near, and of course this kaolin is the result of the decomposition of the granite.

Garnets.—The Arvali schists frequently contain innumerable garnets, but it is not often that they are of sufficient size to be worth picking up. There are, however, extensive workings for them at Sarwar, 20 miles south-east of Nusseerabad, at Rájmahál in Jeypore, and at Maga in Oodeypore.

The Sarwar workings consist of a number of pits sunk in a narrow belt of mica schists, in which numerous granitic intrusions occur. The whole length (upwards of a mile) of the outcrop of the schists is burrowed in search of the garnets. Those I saw from the mine were of good colour and size, but badly cut.

The workings at Rájmahál and Maga are not quite so extensive; but they occur on the same geological horizon and were conducted in the same manner.

All of these workings are now abandoned.

Rock crystal.—Rock crystals were formerly obtained from some small pits sunk in the quartzites at Aurangpur, about 15 miles south of Delhi. The pits are now abandoned and fallen together, but the small crystals of quartz spread about round the pit are very numerous. Probably the rock crystal was obtained from some quartz vein running through the quartzites.

Marble.—Marble is of frequent occurrence among the Arvali rocks, and is extensively quarried in several places. It is generally white, but coloured marbles are occasionally met with, as at Kho and Baldeogarh, and black marble is found in the Motidongri ridge in Ulwar.

The most extensive quarries are those of Makrána, situate on the western edge of the Arvali range in Jodhpore. The marble forms a long ridge running nearly north and south. It is nearly vertical and regularly bedded; and some of the beds being upwards of 2 feet in thickness, large blocks can be obtained. The quarries are confined to about 20 feet of the section, but extend in length for several hundred yards.

Marble is also extensively quarried at Jheri, in Ulwar, and Raialo, in Jeypore.

A coarse kind of marble is quarried at Sarangwa, about 6 miles west of Desuri, on the western side of the Arvali range, in Oodeypore.

Steatite.—The steatite or soap-stone of which the models of the Taj and other ornamental carvings are made at Delhi and Agra is, I believe, quarried in the ridge at Mora Bhandári, about 12 miles north-west of Hindaun, in Jeypore.

FURTHER NOTES ON THE CORRELATION OF THE GONDWÁNA FLORA WITH THAT OF THE AUSTRALIAN COAL-BEARING SYSTEM, by OTTOKAR FEISTMANTEL, M.D., *Palæontologist, Geological Survey of India.*

In my Talchir-Karharbari flora¹ I had an opportunity to point to the greater resemblance of this flora to that in the Bacchus-marsh beds in Victoria, than to that of the New-castle beds, from the great abundance of the genus *Gangamopteris* in both, and I quoted a passage from a letter of Mr. C. S. Wilkinson, Government Geologist, to the late Rev. W. B. Clarke, which the latter had sent me for perusal, and from which it was apparent that Mr. Wilkinson assigned to our coal flora a higher position than that of the New-castle beds and lower coal-measure flora. In my notes to Mr. Clarke, which he published in his "Remarks on the sedimentary formations of New South Wales,"² I assigned

¹ Pal. Ind., XII—1, p. 31, 1879.

² Sydney, 1878, 4th edition, pp. 163—164.

to the Bacchus-marsh sandstones a position which would bring them on about the horizon of the Hawkesbury beds in New South Wales. This seemed natural, as the Bacchus-marsh sandstones are considered as Lower Mesozoic,¹ and the Hawkesbury beds overlying the upper coal-measures or New-castle beds were treated of by the late Rev. W. B. Clarke under the heading "Mesozoic or secondary formations."²

I have since received several communications from Mr. C. S. Wilkinson on his observations of certain physical phenomena in the Hawkesbury beds, which would tend further to correlate these beds with the Bacchus-marsh sandstones, in which similar phenomena were observed. As Mr. Wilkinson has lately published these observations in a paper in the Journal of the Royal Society of New South Wales (December 1879), and has favoured me with a copy of the same accompanied by a letter, in which again reference is made to the Hawkesbury beds, I may, besides from this paper, quote also from his previous letters.

In a letter dated 30th September 1878, Mr. Wilkinson wrote thus:—"I have noticed certain deposits in the Hawkesbury series, apparently due to ice action, which would seem to confirm your view as to the correlation of that series and the Bacchus-marsh beds (in which Daintree has described the occurrence of glacial deposits) with your Talchirs. Yet it is strange that in the Hawkesbury beds we have not found the *Gangamopteris*, which is so abundant in the Bacchus-marsh and Talchir series."

The absence of *Gangamopteris* would in this case be no objection against a correlation of the Bacchus-marsh beds and Hawkesbury beds, because the correlation of the Indian Talchirs with the Ekka beds in South Africa and with the Permian Breccia in England is also based upon these similar physical phenomena only.

In a subsequent letter dated 25th October 1879, Mr. Wilkinson wrote again thus:—"Recently in company with Dr. von Haast, F.R.S., of New Zealand, I again examined the Hawkesbury beds, and the Doctor quite coincides with the views which I mentioned to you in a former letter, that these beds contain many ice-borne boulders."

In his recent letter dated 20th July of this year, he again writes with reference to the Hawkesbury beds:—"Your correlation of the Hawkesbury beds with the Bacchus-marsh beds is, I think, correct, yet it is very strange that in the former we do not find the *Gangamopteris*. This, however, may be due to the fact that in Victoria the *Gangamopteris* has only been found near the ancient margin or shore-line of the formation where the latter junctions with the Silurian, whereas our Hawkesbury fossils were obtained from beds many miles from the margin of the formation, so that the *Gangamopteris* may yet be found when searched for near the margin."

¹ McCoy: Prodr. Pal. Victoria, Decade II (*Gangamopteris*). Brough Smyth: Report of Progress, etc., 1874, p. 34.

² Mines and Mineral Statistics, etc., 1875, p. 181 *et seq.*

From his published note (*l. c.*) the following passages may be quoted (pages 2 and 3¹).—"Had the boulders of soft shale been deposited in their present position by running-water alone, their form would have been rounded instead of angular. It would appear that the shale beds must have been partly disturbed by some such agency as that of moving ice, the displaced fragments of shale becoming commingled with the sand, and rolled pebbles carried along by the currents.

"From their lithological character, the Hawkesbury rocks appear to have been formed in a comparatively shallow sea which was subject to rapid and changing currents. it is on the rocks near the ancient shore line that we should more especially expect to find ice-grooved pebbles, but none have yet been discovered.

"I may here remark that the sandstones and conglomerates (*Gangamopteris* *beds*) of Bacchus-marsh, in Victoria, have been correlated by Dr. Feistmantel with the Hawkesbury series of New South Wales. Some years ago I assisted the late Mr. Richard Daintree in making a geological survey of the district in which these conglomerates occur, and both Mr. Daintree and Mr. A. R. C. Selwyn, F.R.S., then Government Geologists, in their published reports have expressed their belief that glacial transport had been concerned in the deposition of these rocks."

From all these notes it appears evident that there are in the Bacchus-marsh beds and the Hawkesbury rocks certain physical phenomena by which these two formations may be correlated: and in the 4th edition of his Remarks on the sedimentary formations, &c.,² Mr. Clarke again treats of the Hawkesbury beds under the heading of "Mesozoic or secondary formation;" and in another place (*l. c.*, p. 155, Appendix XVIII) as supracarboniferous. As regards their geological position, it may be mentioned that they overlies the "upper coal-measures" or "New-castle beds" which represent the close of the palæozoic rocks in Australia.

This correlation of the Bacchus-marsh beds and Hawkesbury rocks is of no small importance with regard to our Indian coal flora; for, as mentioned before, the Talchir-Karharbári beds show the closest relation to the Bacchus-marsh beds, not only from a palæontological point of view (predominance of *Gangamopteris*), but further also from the phenomenon of "ice-borne" boulders in the Talchir and the Bacchus-marsh beds; and consequently the Hawkesbury beds would have to be placed also on the same horizon. This would have the necessary consequence that the flora of the Damuda series and that of the Australian coal-beds would differ in range, the former being *above* the Talchirs, the latter *below* the Hawkesbury beds. The case might be illustrated thus (also including the South African formations):—

¹ This refers to the pages of the abstract, the volume of the Journal of the Royal Society, N. S. W. (Vol. XIII, 1879) in which this note is published not being yet at hand.

² Sydney, 1878, p. 70.

		AUSTRALIA.		
SOUTH AFRICA.		INDIA.	VICTORIA.	NEW SOUTH WALES.
Jurassic beds.	} Gondwana system in India, a continuous series of beds.	Upper Gondwānas (<i>Glossopteris</i> , very rare).	Upper mesozoic (Bellarine beds).	Mesozoic (Clarence river).
Karoo beds (<i>Glossopteris</i> , frequent).		Panchets and Damudas (<i>Glossopteris</i> abundant in the latter).		Wianamatta beds and
Ekka bed (Boulder bed, ice-action).		Karharbāri and Talchir (<i>Glossopteris</i> , less; <i>Gangamopteris</i> , predominant). (Talchir boulder bed, ? ice-action).	Bacchus-marsh-beds. (<i>Gangamopteris</i> , abundant; Boulder bed, ice-action).	Hawkesbury rocks ;
				(Boulder bed, ice-action).
Unconformity, break.		Unconformity break.	Unconformity break.	Upper coal measures. (New-castle beds ; <i>Glossopteris</i> , abundant). Upper marine beds. Lower coal-measures. (<i>Glossopteris</i> , first appearance). Lower marine beds.
Devonian.				
Silurian.				

This list does not need any further comment. It would appear that the unconformity and break, which exists in Africa, India, and Victoria, between the Ekka beds, Talchir beds, and Bacchus-marsh beds respectively, and their underlying rocks, is in New South Wales filled in between the Hawkesbury rocks and the Devonian beds by the series of the Australian coal-bearing beds. If this surmise be correct, then an older age, than carboniferous, for the Vindhyan of India, would be an almost necessary consequence.

NOTE ON REH OR ALKALI SOILS AND SALINE WELL WATERS, by W. CENTER, M.B.,
Chemical Examiner, Punjab Government.

A reference was made to this office by Government regarding the treatment of reh or saline soils by chemical manures. My predecessor, Dr. Brown, had written a report regarding the use of nitrate of lime as a remedy, and a copy of this was asked for. It could not be found in the records of the office, but I afterwards found that it had been published in the Selections from the Records of the Office of the Financial Commissioner, and the gist of it was embodied in Powell's book on Punjab Products. As I had made numerous analyses of such efflorescences, and studied their connection with saline well waters, samples of which I had analysed from all parts of the Punjab, and as I had an opportunity of observing and learning something of similar soils known as alkali soils in the Utah

Basin and other parts of America, and of the methods used to reclaim them, I beg to submit a few notes on my observations. I am indebted to Captain Ottley, of the Irrigation Department, and Mr. Miller, Secretary to the Financial Commissioner, for access to the literature on the subject in the form of reports to Government. I propose considering more especially the chemistry of the production of those salts and the conditions of their accumulation in soils and in the underground water,—points intimately connected with each other, and equally important in the agricultural and sanitary aspects. The efflorescences consist chiefly of sodium chloride and sulphate in varying proportions. In addition there is sometimes carbonate of soda, and I have usually found some magnesian sulphate. In certain localities the last-named salt is in very considerable proportion. In other cases nitrate of lime or alkali is present.

2. Various theories have been started regarding the origin of these efflorescences, the oldest being probably the marine theory.

Marine theory. According to this the Indo-Gangetic depression was considered to be an old sea bed, the soil of which became impregnated with salts from the existence of shallow “rans” and lagoons in a former geological age. In favour of this it might be mentioned that there is certain geological evidence that an Eocene sea covered the Punjab plain, its shore coinciding with some part of the outer slope of the Himalaya, with a gulf or gulfs penetrating the mountains as far as the valley of the Upper Indus. On the other hand, to the east of Kumaun and to the north of the Gangetic valley, the situation of this shore line is obscured till the Assam region is reached. The theory of recent marine impregnation is now entirely to be abandoned. It is proved beyond doubt that the whole of the materials of the Indo-Gangetic basin are fresh water alluvia to an unknown depth, and consist in fact of the debris of the Himalayas carried down by its drainage and deposited in this immense depression. There are no deep natural sections in which to observe the structure, but in the Umballa boring of 701 feet, the Calcutta boring of 481 feet, and that near Rajanpur of 464 feet, nothing but fresh-water alluvia were met. We do not speak here of the Salt Range region, in which are accumulations of salt as old as the Silurian period.

3. The true origin of reh or alkali efflorescence is the decomposition of the elements of rocks and soils which is continually going on under the action of air and water. The accumulation of the resulting salts in superficial soils or in subsoil waters depends on various conditions of chemical constitutions and permeability of soils, and on the nature of the surface and subsoil drainage, which will be considered in detail.

4. If the rain water that runs off the surface of the hills be examined, it is found to have washed out appreciable amounts of soluble salts, chiefly carbonate of lime and alkaline chloride and sulphate. If such water runs off crystalline or schistose rocks, the amount of salts washed out may be extremely small,—even 2 grains per gallon, as at Dalhousie. If it runs off a loose decomposing rock the quantity may be considerable,—for example, 8 grains near Murree. The rainfall that percolates the debris of the decomposed rock which covers the surface of the hill-sides and fills up the channels of ravines issues in springs at lower levels, and is found to contain

much greater proportions of the same salts. This water not only comes in contact with a larger quantity of degraded rock and washes out its soluble salts, but it takes up more carbonic acid from the air in the pores of the ground, which is rich in this gas, and this dissolves more lime and magnesian carbonate. From 10 to 25 grains per gallon are found in springs in clean soils in various hill stations. In the hill stations themselves, where the porous subsoil becomes loaded with sewage impurity from human habitation, the dissolved salts and organic impurity may be very great. For example, in the bazar well at Murree I found 35 grains per gallon in which were 12 grains of common salt. This last is, however, a sanitary fact, and I wish at present to speak generally of the saline ingredients washed out of such soils not contaminated by human occupation.

5. The soluble substances produced by rock decomposition and dissolved by water are remarkably uniform in their nature, though varying in amounts, both relative and total, according to the nature of the decomposing rock or soil. It may be generally stated that the earth water shows a fugitive acidity from the presence of free carbonic acid and a slight permanent alkalinity from the presence of alkaline carbonate, but that the main ingredients are carbonates of alkaline earths, chiefly of lime, and alkaline chlorides and sulphates, chiefly of soda. Other ingredients are generally in smaller amount, such as lime and magnesian chlorides or sulphates forming the permanent hardness, also silica, traces of iron, &c. Of course in special formations it may be highly charged with peculiar salts, and may even form what are called mineral springs; but we are speaking generally of the body of water that filters from the hill-sides, and either sinks into the underground strata of the plains or finds its way into the streams and rivers, and thence into the sea, the great natural reservoir of the soluble salts washed out of the earth. The waters of the Punjab rivers which I have examined, the Ravi, Jhelum, and Indus, contain 8 to 15 grains per gallon, varying according to the floods. The amount of soluble salt capable of efflorescence varies from about 2 to $4\frac{1}{2}$ grains. The river waters are most concentrated when they are at the lowest. At that time they are supplied by the water that has filtered through the soil and subsoil of the higher regions, and has thus taken up more salts. In the hot weather, when the glacial water comes down, and in the rain floods at the end of the hot season, the dilution is at its highest. Other glacial rivers and those subject to annual floods show the same thing. For example, the total solids in Nile water vary from $9\frac{1}{2}$ to $14\frac{1}{2}$ grains per gallon.

6. To explain the ultimate origin of these salts we have to consider the action of the oxygen and carbonic acid in rain water on the rock elements. With the exception of the limestone strata, which consist of carbonate of lime, often with carbonate of magnesia, all great rock formations are composed of silica and silicates, chiefly of alumina, lime, magnesia, soda, and potash, with smaller amounts of iron and other metals. Such is the constitution of the granites, gneisses, slates, traps, &c. The old sedimentary rocks are similar in composition, being formed by the disintegration of these. The recent alluvia of the plains consist of finely-divided debris of the limestone and silicious groups, and in them the chemical decomposition going on under the influence of air and water is much intensified, owing to the state of fine division

which favours chemical action, and because the constituents of the soil are further advanced in the path of degradation.

7. In order to understand the slow chemistry going on in the ground, we have to conceive the outer shell of the earth generally covered with more or less vegetable mould, and permeated to its greatest known depth by meteoric water. There is no rock, however compact, and there is no depth to which man has penetrated, in which water is not found to have permeated by pores, cracks, or fissures. The great agent of change is the carbonic acid of the air. This is dissolved in rain water, which also dissolves more from the decaying vegetable mould and from the air in the pores of the ground, which is rich in this gas. It has two great functions. It attacks the silicates of the alkalis and lime, forming carbonates. It further dissolves the carbonate of lime, enabling it to be transported by water and to be redeposited on evaporation. From the limestone rocks the water takes up carbonate of lime and magnesia, which dissolve in its free carbonic acid, and in such formations it becomes very hard. The amount of carbonate of magnesia dissolved is always much less than that of lime. In the silicious rocks the felspathic family of minerals decomposes most readily. These consist of silicates of alumina and alkali, with generally small quantities of lime and magnesia. The white or soda feldspar, which contains more soda than potash, is a common ingredient of the Himalayan rocks, and the decomposition of this in soils may possibly to some extent account for the very great excess of soda over potash salts. The chief reason, however, depends on the fact which has been experimentally verified, that in a silicate containing both potash and soda the latter is dissolved out with greater facility and in much larger quantity than the former. The process of decomposition consists in removal of the alkali by the action of carbonic acid, while water is taken up, leaving hydrous silicate of alumina or clay. The presence of alkaline water also assists in promoting the breaking up by dissolving some silica. Another group, the lime silicates, is also readily decomposed by the action of carbonic acid or alkaline carbonate, and forms an additional source of carbonate of lime. On the other hand, the talcose rocks, which contain magnesian silicate, are hardly attacked at all. This magnesian metamorphosis of rock, which is very extensive and very ancient, is also the most permanent, and apparently a final one. We have thus accounted for the alkaline carbonate and carbonate of lime. The earth water is almost always slightly alkaline, and this plays a most important part in the decomposition of the silicious rocks and their metamorphosis. The alkaline carbonate rarely, however, appears in large amount, because it partly expends itself in decomposing silicate of lime, thus forming carbonate of lime, and if free carbonic acid is present, this will be dissolved and carried away by the water. If magnesian or lime sulphate be present, the carbonate of soda with these will produce lime or magnesian carbonate; while sulphate of soda will be found in the solution. It thus happens that the waters of the rivers contain apparently no alkaline carbonate, but show a permanent neutral re-action. All the river waters, in addition to carbonate of lime, which is their chief ingredient, contain also lime and magnesian sulphates which there has not been enough alkaline carbonate to decompose.

8. The circulation of the sulphur that occurs in the earth is very interesting.

Origin of sulphates. That which forms the sulphates in the earth-water appears to be derived from the sulphurets, especially of iron, which are so universally diffused in rocks, and from the gypsum rocks, which, however, form an insignificant portion of the strata. The sulphate of lime being moderately soluble may be readily taken up by water. The sulphurets become oxidised by the oxygen in air or water, leaving red iron oxide, which gives the yellow or red colour to soils and clays; while the sulphuric acid attacks the silicates and unites with soda or lime. In the strata of the earth are found deposits of sulphates of lime, but these appear to have been deposited from solution by infiltration, or by evaporation, as in the Salt Range. Their ultimate origin is probably the same as that just indicated. The presence of sulphate of lime in soils leads to the production of sulphate of soda. The former salt is slightly soluble, and as the earth-water contains alkaline carbonate, mutual decomposition leads to the formation of carbonate of lime and sulphate of soda. This partly accounts for the excessive proportions of sulphate of soda often found in reh. The sulphates may be again reduced to sulphides by organic matter from the vegetable mould or other sources, which accounts for the presence of sulphuretted hydrogen in dirty well waters rich in sulphates.

9. As regards the chlorine of the alkaline chlorides, there is more difficulty.

Origin of chlorides. Chlorine is not an important chemical constituent of any common minerals forming rocks, but there is no rock that on being powdered and washed with distilled water does not show its presence. The only explanation known of its appearance lies in the fact that, though generally in minute quantities, it is the most universally diffused substance we know. Even in air a chemically clean platinum wire cannot be exposed for some time without showing the sodium line in the spectroscope due to sodium chloride which can be extracted from the air dust.

10. There is next to be considered the chemistry going on in the decomposition of the debris of the rocks forming the plain. It is in a more finely-divided state, and is therefore in a condition more favourable for chemical action, and besides the constituents are in a further advanced state of decomposition than in the fresh rocks. The action that has been described is therefore intensified. It has been proved by experiment that it is from the most finely-divided clay (felspathic) particles of soils that most of the soluble substances can be extracted. These particles are so extremely fine that under the microscope they are seen only as minute dots. The other small particles which are of measurable dimensions are silicious, and yield to acids only a slight amount of soluble matter.

11. There are three points to be considered,—the action that takes place on the surface, that which takes place in the strata permeated by the underground water, and also the relations between the two.

12. On the surface undoubtedly the greatest amount of decomposition goes on

Surface production of salts. from the united action of air, moisture, heat, and light. This produces the perennial supply of soluble salt necessary for the growth of plants, and in cultivation it is assisted by turning up and

pulverising the soil and acting on it by water. In countries with good surface and underground drainage there is a constant escape of these salts, and the difficulty may be how to get enough of them. In many parts of our plains circumstances favour their accumulation, and the question is how to get rid of the excess. I have frequently taken samples of soil and subsoil from places where there were efflorescences and where there were none, and on washing out the soluble substances with boiled distilled water found that they were similar, but different in amounts. They always consisted chiefly of alkaline chloride and sulphate, with often small quantities of alkaline carbonate, and frequently larger amounts of soluble magnesian salt, sulphate or chloride. Another experiment was to take a sample of reh soil and wash it repeatedly till no trace of soluble salts could be found. It was then dried and thoroughly mixed and a portion tested again to see that no soluble salt was present. It was then placed on a filter and covered with porous filter paper so as to exclude dust, but allow evaporation, and the bottom of the glass filter was corked. It was frequently watered with distilled water charged with carbonic acid and exposed to the heat and light of the sun in the hot weather for nearly three months. At the end of that time it showed no efflorescence, but on being washed with distilled water the solution showed the presence of considerable quantities of alkaline chlorides and sulphates. This experiment proved that in that species of soil a sensible production of reh salt may take place in a few months. A similar sample irrigated with ordinary well water rapidly developed an efflorescence owing to the presence of salts in the water. There is nothing particularly novel in these results. Experiments have often been made of grinding down the solid rock from the debris of which the adjoining country was formed. On washing out the powdered rock the solutions were found to contain the salts of the water of the district; indeed it is always possible to account for the composition and proportions of the ingredients in a water draining any area if the structure and composition of the rocks are known.

13. To estimate approximately the decomposability of a soil, the simplest method is to dry and weigh a sample and wash out from it the soluble salt already present. On drying and weighing the residue and deducting its weight from the original there will be found the soluble salt (along with some organic matter). This is the result of decomposition already accomplished. The solution may be tested in the usual way, by evaporation to find the total dissolved matter, and by ignition to find organic matter. The washed residue of earth is then ignited to expel all remaining organic matter, and treated with hydrochloric acid, which will decompose and dissolve the materials which are in an easily decomposable state. The solution will contain lime, magnesia, alumina, and iron, and also the alkaline bases capable of efflorescing. On deducting the undissolved residue from the former, a figure will be found, which will be an approximate index of the facility of decomposition of the soil. The hydrochloric acid solution can be examined in the usual way if required by first precipitating the iron, alumina, and phosphates of the alkaline earths, then the lime, and afterwards separating the magnesian and alkaline bases. The last will show the salt capable of efflorescing. A more

Approximate estimate
of decomposition in soils:
the Lysimeter.

correct way is to perform an experiment similar to what I have described before with the glass funnel. A zinc box is made open at the top and closed at the bottom, with a false bottom of perforated zinc half way down. The section is usually 1 square foot. Earth is placed above the perforated zinc, and the whole is exposed to the varying conditions of the season and climate, as rainfall, heat, moisture, &c. All water that falls sinks through the perforated bottom, and is collected or evaporates. After some months or a season the solution in the bottom of the box and the earth are examined in the usual way to find the results of decomposition. Such an instrument is called a Lysimeter, and has the advantage of demonstrating the changes that take place, not by the action of acids, but by the ordinary operations of nature.

14. Another source of generation and accumulation of these salts takes place

Underground produc- in the strata moistened by the underground water. This tion of salts. is partly derived from percolation of rainfall from the surface where it is sufficiently porous. In its passage downwards it washes out any soluble salts it meets and carries them down till it reaches the impermeable stratum. In the second place the air contained in the vegetable mould and porous ground is rich in carbonic acid, and this is absorbed by the water and enables it to dissolve more lime and magnesian carbonate, which accounts for the much greater hardness of subsoil waters. In the third place the alkaline water charged with carbonic acid not only promotes the decomposition of the strata through which it filters, but by a constant soakage action on that which it moistens produces still more. The amount produced would be in a great measure proportional to the time the water remains in contact with the stratum. In stagnant underground waters in the middle of the plains, as at Chunga Manga and Wanradaram, the dissolved salts amount to 400 grains per gallon. Another feeder of the underground water is the percolation of hill water that sinks into the porous fringe at the base of the hills. This, however, affects particularly the plain near the base of the hills. The solution formed from the debris on the hillside is much less saline than that from the finely-divided and more degraded materials of the plain. The hill percolation therefore affects the underground water near the hills in two ways. It raises its level by hydrostatic pressure and it makes it less saline by dilution. There is still another source of underground waters in the percolation from rivers, streams, and canals. The neighbourhood of rivers affects the water-level, and very sensibly influences the quality of the subsoil water. Analyses of waters taken from wells near them show that they closely approximate to the river waters, being little more than those filtered. For example, the well water near the Ravi was found to contain from 8 to 15 grains per gallon, that near the Jumna 9·8 to 14 grains. Advantage is now being taken of this in supplying water from such wells to some large cities in the Punjab. The influence on the quality of the subsoil water, however, only exists in the khadar land, or low river valley. In the bhangar, or bar land, the upland that lies between neighbouring rivers, even at short distances from the valley, the water may be highly saline. In the case of canals, as far as my observation goes, there is very little percolation in the districts I have seen irrigated by the Bari Doab Canal, on account both of the impermeability of the soil and

the disposition of the strata. If, however, a canal were made on a natural line of drainage, as I have heard the Western Jumna Canal is, it might influence the adjoining ground in the way I have mentioned in the case of rivers, both as to the water-level and quality of percolating water.

15. When rain water sinks into a soil containing soluble salts, it dissolves them and carries them down till it reaches an impermeable stratum. Medlicott has pointed out the action of the first rain drops in carrying efflorescent salts down, so as to be in a great measure out of the reach of the surface scour of the succeeding rainfall. If the soil is porous, it may gravitate down to the water stratum, which then becomes a reservoir of the surface salts. If it is only slightly porous, as in alluvial soils containing much clay, the soakage is only superficial to one or more feet in depth, and generally in such cases the surface soil is more or less porous from atmospheric exposure, and below it lies a more compact clay subsoil. As rain water contains free carbonic acid, it dissolves also carbonate of lime and magnesia if these be present in the soil. When evaporation succeeds, it draws up the moisture in the more porous surface soil by capillary action. As the water and carbonic acid pass off, the solution becomes more concentrated and carbonate of lime is re-deposited. This last action takes place first, and as the concentrated solution is drawn up to the surface, it finally deposits its most soluble salts on drying as an efflorescence on the surface. An essential condition is the dryness of the climate. In more temperate, but dry regions, as in the Utah Basin and the elevated parks or plateaus of the rocky mountains, efflorescences appear as well as in the scorching plains of India. The action, however, is intensified by heat, which increases evaporation. By similar capillary action the moisture will creep up the sides of objects lying on the ground, such as pieces of brick, and deposit a copious efflorescence. At first it appears in glittering crystals, but as the sodium sulphate gradually loses its water of crystallization, it breaks up into a copious white powder of anhydrous salt, and it is then that it is most apparent. The carbonate of soda behaves similarly, but the sodium chloride does not, having no water of crystallization. Nitrate of soda and lime deliquesce in damp air. During the hot months, the salts, if brought up by rain, melt in their water of crystallization. By the word efflorescence we do not mean here what is known as such in chemical language, that is, the breaking up of a crystallized salt into a powder from loss of water of crystallization. What is meant is efflorescence in the physical sense, or the appearance on the surface of the ground of soluble salts brought up by capillary evaporation. It is true that sulphate and carbonate of soda effloresce in the chemical sense, but chlorides and nitrates do not.

16. From what has been explained regarding the origin of the salts dissolved out of the earth, it can be understood how the solutions can naturally be divided into two groups, whether they be river and canal waters, or well waters, or solutions formed when rain water soaks a saline soil. There are first the neutral solutions from which carbonate of soda has almost or entirely disappeared, having been used up in decomposing any soluble lime or magnesian sulphate or chloride and precipitating their carbonates. To this belong the river and canal waters, the chief ingredient of which is carbonate of lime with less amounts of

magnesian carbonate held in solution by free carbonic acid. There is present probably next in amount soluble salt of lime and magnesia, sulphate or chloride—the magnesia in smaller amount. The alkaline chloride, though the most constant ingredient in all waters, is in small amount, from $\frac{1}{2}$ grain to 2 grains, and the alkaline sulphate in about equal or larger quantity. In the majority of well waters in the plains in my experience there is high permanent hardness, indicating lime or magnesian sulphate or chloride, and sodium carbonate is deficient. The total dissolved salts is in fresh well waters about double that in rivers and canals, and may rise in saline wells from 10 to 40 times the amounts, the increase being chiefly in carbonate of lime and alkaline chlorides and sulphates.¹ The second group of waters or solutions is that containing carbonate of soda. In these there is generally little permanent hardness, or soluble lime or magnesian salt. If these two groups on evaporating produce efflorescence, in the first we may have sodium chloride and sulphate, and any magnesian sulphate, if present; in the second we may have sodium carbonate with sodium sulphate and chloride, but no lime or magnesian salt. During the process of drying, which leads to the efflorescence, the first thing that occurs is the deposition of lime and magnesian carbonate, as the free carbonic acid disappears. Subsequently, sulphate of lime being only little soluble would deposit, and the highly soluble salts, including sodium carbonate, chloride and sulphate, magnesium and calcium chloride and nitrate and magnesium sulphate, would be capable of efflorescence. These salts, however, are not deposited as they exist in solution, as new laws come into play. The chief of these is, that during evaporation the least soluble salt that can be formed is first deposited; but this is modified by two other laws, the tendency of certain compounds to form double salts, and the tendency of substances with the same crystalline form to crystallize out together. The efflorescences thus produced consist of three groups; 1st, the neutral, containing no carbonate of soda, consist chiefly of sodium chloride and sulphate, and frequently magnesium sulphate; 2nd, the alkaline, containing carbonate of soda and alkaline chlorides and sulphates, but no lime or magnesian salt; 3rd, the nitrous efflorescences. These generally contain no alkaline carbonate, and consists chiefly of nitrate of lime and alkaline chlorides. Others contain alkaline nitrate, chloride, and sulphate. They are developed where the soil has become loaded with organic nitrogenous matter. In several places about Lahore there is a good deal of magnesian sulphate, and I have observed on twigs of farash trees a saline coating of this salt. Reh is thus not a special salt or mixture of salts, but a very variable compound. It is really the most easily soluble salt in the earth-water, remaining in solution after the deposition of carbonate of lime, &c., on evaporation. The ingredients and their relative proportions are found to vary in different places, exactly as the well waters at different spots differ in saline contents, and in the same area there is a

¹ Though we speak usually of individual salts existing in a solution, this is not, strictly speaking, scientifically correct. If, for example, sodium chloride and lime sulphate be made into a solution, it will really contain quantities also of sodium sulphate and lime chloride, and the amounts of the four salts will depend on the masses of the first two, temperature, concentration, &c. Properly speaking, in recording an analysis, the total amount of acids and bases should be separately recorded. By a conventional rule, however, it is customary to arrange the salts hypothetically.

close relation between the two. The relative proportion of common salt to sodium sulphate was found by Medlicott to vary from 4 to 24 per cent.

17. The re-deposit of carbonate of lime gives rise to those nodules known as kankar. It takes place at the upper margin of the impermeable subsoil. They are not formed by the lime depositing round a nucleus and pushing the other elements of the soil aside. A portion of rather porous soil, consisting of a mixture of lime, sand, and clay, is infiltrated with water retained in it by an impermeable bottom. The carbonate of lime is deposited throughout this porous mass, and cements its particles together till it becomes of a stony hardness. Deposit no doubt also takes place along the outer surface, as each former minute crystal deposited acts as a nucleus for further deposit. The formation is often seen in an incomplete state, nodules of soil having become only partially hardened. The process is essentially one of segregation from the soil itself. Such nodular formations, which are very common with other minerals, as iron oxide, silica, &c., are an example of the simplest kind of metamorphosis going on in rocks and soils. It is not necessarily connected with efflorescences on the surface. The essential condition of its existence is the presence of carbonate of lime, or its ready production by ordinary decomposition in the soil. In soils and sub-soils which supply little lime there may be efflorescences without formation of kankar, as in those consisting of clay and silicious sand. On the other hand, in marly soils, in which there may be little production of alkaline salt, kankar may form without any efflorescence. The analysis of kankar very well illustrates their mode of formation. They show from 20 to 50 per cent. of carbonate of lime, the rest consisting of the mixture of clay and sand of which the soil is composed.

18. To estimate practically the amount of injurious reh in any soil, it should be washed with boiled distilled water and the solution evaporated, then burned to expel organic matter and finally weighed. In the case of the waters of rivers, canals, and wells, they should be evaporated, ignited, re-carbonated, and weighed. The easily soluble salts should then be washed out with a little distilled water and the residue weighed. The portion undissolved consists of lime and magnesian carbonates and some sulphate of lime with small amounts of silica, &c. The difference between the two weights is the amount of salt capable of efflorescing. If one have a record of the analysis of any water, a rough approximation is got by deducting from the total solids the volatile matter (almost all organic), also the removable hardness consisting of carbonate of lime. In addition two grains per gallon of carbonate of lime should be further deducted, as in boiling (in order to remove carbonate of lime), two grains per gallon still remain dissolved. A still further deduction would require to be made for silica, iron, &c., but these are in small amount. I mention these methods of approximate estimation because they are readily applied and are useful for all practical purposes.

19. In considering the conditions that lead to accumulation of salts on the surface or in the underground water, it is to be borne in mind that soils exposed to moisture, air, and heat are continually generating them, and that in some in which the felspathic elements

are undergoing rapid decay the production may be profuse. Also all water, river, canal, or underground, that has washed over or filtered through the ground, contains similar salts and promotes their further production.

20. The simplest case of accumulation is that of a closed basin like the Utah Basin. The surface water washing the salts off the ground has no escape to the sea, and forms an inland salt lake. The soil in such cases is very saline, except in places where there is slope to allow thorough surface washing by rainfall, or permeability to allow the surface salt to be washed down to a deep ground water. In the centre of the depression both the surface and sub-soil and the sub-soil water are loaded with salt. The efflorescences in Utah closely resemble those in the Punjab, the main common ingredients being sulphate of soda, common salt, and often sulphate of magnesia. In some places there is a large amount of carbonate of soda, in others borax is present. In the Caspian Basin the main ingredients are sulphate of soda and common salt. The very opposite case is a hilly or undulating country with sufficient rainfall and good natural surface drainage, the strata of which are also inclined, thus allowing of natural sub-soil drainage till the underground water finds an outlet at the outcrops of the strata, or where they are laid open by natural sections of the country. Here the salts continually formed are either washed off the surface or are carried down to the sub-soil water which drains them off.

21. In examining the state of things in the Indo-Gangetic plain, it is necessary to consider the structure of the country. The Himalayan axes stretching along the north of the plain are elevated cores of granitic gneiss flanked by metamorphic and limestone rocks. To the south of this is the Siwalik fringe with its dűns, consisting of clays, sandstones, and conglomerates. These are fresh-water deposits formed by river and torrent action in the tertiary period, and having suffered displacement by the Himalayan elevation, they are seen to pass with great undulations and numerous fractures under the strata of the plain. This formation conducts water under the plain. There succeeds to this the recent gravel deposits from the outer hills, brought down by river and torrent action, similar to that which caused the Upper Siwaliks, and known as the Bhábar. This is extremely porous, and a great part of the water of the streams passing over it sinks into the ground and issues in springs at a lower level in the adjoining part of the plain, which is known as the Terai. Part also sinks beneath the plain and raises the ground-water level. The great alluvial plain itself is composed of horizontal strata. Near the hills are gravel deposits, but further off the soil and sub-soil to an unknown depth are composed of deposits of clay, sand, and mixtures of the two in various proportions, according to the stream or lake action that deposited them. Diffused through these are found mica and small quantities of carbonate of lime, which makes soils more or less marly, and iron oxide which gives them a yellow or red colour, and minuter amounts of sulphate of lime and other salts. From numerous well sections it is seen that these alternating permeable and impermeable beds of sand and clay are not continuous, but that they thin out and are replaced horizontally by others. This is observed even at

short distances. Possibly many of the sheets of clay may have more or less of a basin form. The important points for us to remark in considering the surface and sub-soil drainage are that this immense plain has an average breadth of about 200 miles, that practically the Gangetic and Punjab plains are one, the water-shed between the two being only perceptible by accurate scientific measurements, and that its length is about 1,200 miles. There are also no deep natural sections exposing outcrops of the deep strata so as to allow of escape of underground water to the sea. In consequence of the very small surface slope, and on account of the horizontal disposition of the strata over such an enormous area, the conditions as regards drainage approach to those of a basin. The surface drainage is weak, but ultimately finds its way by the rivers to the sea, but the underground drainage is usually imperceptible.

22. As regards the production of efflorescences, we have further to consider that in the Punjab there are three belts of plain. That adjoining the hills, the sub-montane tract, has a plentiful rainfall and moister air; south of this is a sub-desert tract with small rainfall, and still further south is the desert country with deficient rainfall. In the sub-montane belt the rainfall is sufficient to scour the surface, and as it is more permeable from the presence of gravel and sand, and has greater slope, the surface and subsoil drainage are more efficient. In the other two tracts the working of these agencies is defective. In the hills themselves the annual rainfall of a series of years is as follows: Murree, 56·8 inches; Dharmasala, 123·2 inches; Simla, 68·6 inches. This does not include snowfall however. In the sub-montane belt we would have—Rawalpindi, 32 inches; Sialkot, 39·3 inches; Gurdaspur, 33·1 inch; Hoshiarpur, 36·5. Of the less-watered region there is Lahore, with 19·3 inches; Shahpur, 14·5 inches; Sirsa, 14·5 inches; while about Mooltan the rainfall is 6·9 and at Dera Ismail Khan 8·2.

23. The simplest case to consider is that which occurs in the more desert country, in which the rainfall is only enough to moisten the surface and promote decomposition. If the soil is sandy the dissolved salt is carried down to the underground water and the accumulation takes place there. If the ground is not porous, as where clay predominates, only the upper portion is soaked, and on drying the soluble salts are brought to the surface. Instances of both these cases are found everywhere along the southern portion of the Punjab plain. In the middle portion of the plain, where the rainfall may go up to 20 inches, similar actions take place. The first drops of rainfall dissolve any efflorescence and sink into the ground, carrying it out of the reach of surface scour, which on account of the flatness of the plains and small rainfall is slight. In the more porous portions the salt is carried down to the underground water; in the more impermeable it is brought to the surface by evaporation. It thus happens that in certain places there is a scum of efflorescence on the surface, while generally the ground water is saline. These remarks apply to the Doab or Bhangar land, the more elevated part of the plain lying between adjacent rivers. In this the water lies at a considerable depth, from 30 to 100 or more feet, and is more or less saline; in many places on digging deeper to another stratum fresher water is found. In the other great plains of the earth where the climate is dry

and like conditions of soil prevail, similar efflorescences are developed. In the dry pampas of South America they consist chiefly of sodium sulphate with some common salt; in the Siberian steppes, of sulphate of magnesia along with sulphate of soda and common salt. They are likewise found in the Russian steppes and the Tibetan plateaus.

24. The Khadar, or low-lying river valley, cut out by recent erosion from the old alluvial plain, usually shows little or no saline accumulation on the surface and none in the underground water. Here the circumstances are all different. In fact the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope. Accordingly, the water percolating from the river forms a subterranean stream, gravitating down the river-course and accompanying the main stream. Its extent depends on the permeability and arrangement of the strata and the resistance of the porous beds along which it moves. In the beds of dry nullahs this gravitating water may be met on digging in the dry channels. If the underground water were stagnant, remaining long in soakage contact with the water-bed, it would become more or less saline, whereas it is found to resemble the river water filtered, though of course it has taken up some ingredients from the earth, chiefly more carbonate of lime. In two cases in which I examined the water in beds of dry nullahs, I found it much less saline than that of the surrounding plain. In the Khadar land the water lies near the surface, and may be within the reach of capillary evaporation, which would produce efflorescences, as it often does to some extent. But in consequence of the occasional washing by floods, and of the underground circulation I have described, there is no permanent accumulation either on the surface or in the ground-water.

25. One of the most interesting and important cases is that in which the
 Accumulation by evaporation from a shallow water table. ground water lies close to the surface within the reach of capillary evaporation, thus furnishing an unlimited supply of efflorescence. The enquiry made by the Aligarh Committee chiefly referred to this instance. It was considered that the ground-water level had been raised by percolation from the canal, assisted by hydrostatic pressure, in consequence of the canal being above the level of the country. Other causes assigned for the rise were the obstruction to surface drainage by canal and railway embankments acting as bunds, and the practice of profuse irrigation in flooding. All these would lead to an increased body of water sinking into the ground, carrying earth salts in solution to be again brought up by capillary evaporation from the shallow water table. It is very important to be able to estimate how much is due to each of these agencies, as on the decision of this point would depend the remedial measures to be applied, such as the lowering the level of the canals, their realignment on the high Bhangar land instead of on the lower ground, the restriction of profuse irrigation, the relieving of the surface drainage, and the establishment of artificial sub-soil drainage. I am unable to enter into the merits of these most interesting points because I have never had an opportunity of making observations on an area where this mode of generation of reh was going on to a serious extent. The only portions of country I have seen in which the ground-water lies very near

the surface are the plains adjoining the hills and the Khadar lands or river valleys. In the former the rainfall is more plentiful, the slope of the surface and deep strata are better, there is more moisture in the air, and therefore less evaporation. All these tend to prevent accumulation of salt below and efflorescence above. In the latter the washing of the surface by the floods and better subterranean drainage may account for the want of accumulation. In the parts of the Bari Doab Canal which I have seen, the ground-water lies at a depth that is totally out of the range of capillary action, and the strata consisting of alternating clays and sands are so impenetrable that percolation can have little effect on the water level. Captain Otteley informs me that on the Bari Doab and Upper Sutlej Inundation Canals the curves of the rise and fall of the well waters markedly follow those of the rainfall and do not appear to be affected by irrigation. I did not find any marked difference in the water levels of the wells near and at a distance from the canal about Lahore. A still better proof was that the salinity of the wells was not altered by proximity to the canal. If percolation to any extent existed, the wells close to the canal ought to be fresher than those at a distance. In the part of Lahore occupied by the railway station and barracks the ground-water is salt. At the end of the hot weather I found that a well a few yards from the canal contained as much salt as others far off. After the rains the same well waters were found to be so diluted as to contain less than one-half of the former amounts. The depth from which capillary evaporation can take place is also a question that ought to be investigated by observation and experiment. Much of course depends on the porosity of the soil, but in the most favourable cases one would fancy, from the known laws of capillary force, that the action would only be through a few feet, unless assisted by hydrostatic pressure. At the village of Baoli, on the Western Jumna Canal, where the reb action is very pronounced, the depth from the surface of the ground to the water table (as shown by measurements of an unused well) is 8 feet. It is said that before the Western Jumna Canal was re-opened in 1819, the water in wells about the part lay at a depth of 60 to 70 cubits, and this tradition appears to be confirmed by inspection of the records of other wells which had been sunk to as much as 116 feet, and in which now there are 62 feet of water. On the banks of water-courses and canals about Lahore in salt soils one often observes two lines of efflorescence, one a few feet above the water level at the upper limit of capillary soakage, and another some distance from the surface, at the base of the surface percolation. As regards the rise in the well water levels said to be caused by canals, it would be necessary to have accurate information as to what those levels were before the canals were made. Probably no accurate record was made before the earlier canals were started, as attention was not directed to the point.

26. There are last to be noticed some other modes of distribution and accu-

Other modes of accumulation of alkali salts. Irrigation by flooding and mulation.

allowing the water to dry on the soil, unless it is very permeable, of necessity leads to production of salt. Not only does the irrigating water contain salt which it deposits as an efflorescence, but it also promotes further decomposition in the soil. The amount of reb in ordinary canal water

might be from 2 to 6 grains per gallon. If well water is used, the accumulation is much greater, because it contains much more salt. In places where the water is sweet, the reh may be about 6 to 15 grains per gallon; where it is salt, it may amount to more than 200 grains per gallon, as at various places on the Railway Line between Lahore and Mooltan. An extraordinary instance is mentioned in the Aligarh Report of a reh soil tried by the most energetic measures without effect. An analysis of this soil would probably have proved that the elements of the soil itself were in such a state of decomposition that most of the measures employed assisted the process. Again, water running off a saline field must necessarily dissolve a portion of its salt, and if it be allowed to run into another and dry, that salt will be deposited. The agency of wind appears to be a slight and very variable one. There is no doubt that wind blowing over a saline country and raising dust transports saline particles. Travellers over the alkali plateaus of the Rocky Mountains are familiar with the irritation caused to the eyes by this mode of transport. All these, however, are of secondary importance. The main points to bear in mind are, that there are several factors causing production and accumulation, and others leading to the removal of earth salts. Of the former there is first the soil itself. This is always generating them, and in certain cases its materials so readily undergo decomposition that perhaps even artificial means may fail to cure the evil. The next chief factor is the water used in irrigation. This always contains reh salts,—the river and canal water in small amount, but the well water often in enormous quantities. In addition, the irrigation water may not only deposit its salt in the soil, but it causes further production in the soil itself. Another cause is the special condition in which the subsoil water lies within the reach of capillary action from the surface, which may give rise to an inexhaustible supply. The factors concerned in the removal are, first, permeability of the soil, which may allow the salts to be washed down to the underground water. If this have a ready outlet, they are removed; if not, there will be a saline ground water; but the surface may show no accumulation if the water table is deep. If, however, the ground-water is a very short distance from the surface, there may be a profuse efflorescence under the usual conditions of dryness of the atmosphere and heat. The second cause of removal is copious rainfall. If the rainfall is copious, it may wash away part of the salts, and this is one of the reasons that in rainy regions alkali is rare. If it is slight and only moistens the soil without scouring it, there will be a continuous production and accumulation on the surface, except when the soil is porous and allows it to be carried down to the ground-water. The third means of removal is by vegetation, which annually takes up its necessary portion of salts and assimilates them. It is frequently observed that in cultivated spots the reh is kept under, while the uncultivated ground around may be covered with it. In connection with this, it is to be remarked that for land plants potash salts are necessary, but it is doubted whether soda salts are essential, except in the case of *Salsolæ*, &c., which grow in soda soils. This may have something to say to the barrenness of our soda reh soils. Another factor to be noticed is the effect of shade produced by vegetation, which prevents the excessive evaporation which brings the salt to the surface. It thus remains more diffused

through the moisture in the soil. Lastly, plants also induce capillary currents towards themselves. The absorbing parts are the rootlets and myriads of hairs surrounding each. These, by the act of absorption, set up capillary currents in the moisture of the soil towards themselves, which compete with capillary evaporation at the surface and tend to the diffusion of the moisture and its salts through the soil as far as the roots extend. It is to be noted that if a soil remain damp, so that the salts are diffused through it, they may do no harm. It is their concentration as a scum on the surface that poisons crops. The moisture round the rootlets forms a solution so saline that the osmotic currents by which the plants are nourished are interfered with and they perish.

27. A very important point materially affecting the question of the cure of reh, is how far reclamation or non-development may be due to diffusion of the salt in the soil. In rainy and damp portions of the plains similar in conditions of subsoil drainage to reh-stricken tracts, we find no efflorescence. How far is this due to surface washing and how far to diffusion? From three experiments made this year, it was found that the rain waters coming off the surface of reh-ground contained a perceptible quantity of the salts. Nevertheless the great fact of occlusion by means of the first soakage portion of the rainfall was proved by the occurrence of a copious efflorescence on the drying of the washed soil. If the rainfall were very copious, would it succeed in washing off excess of salt? This question might be settled by analysis of the total quantities of soluble salt in soils of the rainy and dry tracts of the plains, within the range of surface soakage. As it would be impossible to select two spots precisely similar in conditions of subsoil drainage and constitution of soil, it is evident that no conclusion would be of value except from a great number of experiments.

28. Speaking broadly, the development of efflorescences occurs in India chiefly in a well-marked meteorological area, including the Punjab, except at the base of the hills, similarly the upper part of the North-Western Provinces, and also Sindh and Rajputana. This region is characterised by small rainfall, dryness of the air, and excessive solar heat, each of these as shown contribute to the concentration of salt on the surface. On the other hand, in similar parts of the Indo-Gangetic plain, where there is more copious rainfall, this of itself by keeping the soil moister causes diffusion of any salt present through the soil. Again, the sheet of air which covers the ground contains more moisture and acts in two ways in preventing surface concentration. It diminishes the effect of solar heat, because, as Tyndall has shown, the invisible vapour of water absorbs a great deal of the heat, thus preventing damp regions, such as Lower Bengal, from reaching such high temperatures as the dry regions of Upper India, even though the latter are of higher latitude. In addition, there is more cloud in the damp regions which also abstracts solar radiation, whereas in Upper India the sky is cloudless most of the year. Again, the presence of a moister sheet of air over the ground abstracts evaporation, which takes place in proportion to the dryness of the air. It is very desirable that a series of experiments should be made regarding the total salts occluded in the drier and moister parts of the plains within the ranges of surface soakage and evaporation.

29. As regards the effect of reclamation, further experiments are also required, in order to show how much is due to removal or diffusion of the salts. I estimated the total salt in reclaimed soil and in adjoining reh-ground to the depth of 3 feet at two places near Lahore. Equal columns of earth were taken up by boring with a tube. The result was negative, as in one case the reclaimed soil contained a little less salt than the adjoining reh-ground, and in the others rather more than a third less. No conclusion of any value can be drawn except from a large number of estimates, the variables affecting each case being also taken into account.

30. The state of porosity of the soil has also a great deal to do with the appearance of the efflorescence. Nothing is apparently more capricious than the way it shows itself in one spot of a field and not in another. This may be partly due to difference of constitution of the elements of the soil, but there is no doubt that another cause must be the facility of capillary evaporation due to the variable mixtures of sand and clay of which these alluvial soils are composed. This also suggests a question that might be of importance, as to how far reh soils could be improved by additions of sand or clay so as to affect their capillary action.

31. I conclude this paper with some practical remarks regarding the methods of dealing with saline efflorescence agriculturally; but these I wish to be considered suggestive more than any thing else, as I cannot pretend to any experience in that line. When visiting Utah I was very much struck on finding that the saline efflorescences of that basin were similar in nature to those I had seen and studied in India. I made enquiries into the ideas current on the subject and the methods of reclaiming the soils. Brigham Young's notions of natural philosophy were both extremely simple and at the same time shrewd, as would be expected from an uneducated, but practical and successful man. He said: "There is salt in every thing. Water has salt, plants have salt, and earth has salt; and the Bible tells us that if the earth have lost its salt it is useless. A certain quantity of salt is necessary for vegetation; in our country we have too much of it, and we get rid of part of it." He referred me to Mr. Woodruff, who was Secretary to the Agricultural

By sluicing and irrigation. Society, and to some of the best farmers, to see what was done. The plans adopted were the following: A salt field was ploughed and small runlets of fresh water were sent down the field, at short distances apart, washing the soil and running off into the drainage of the country. Another method was to plough up a field and make a terrace round it and then flood it. The water was allowed to soak for some time till it had dissolved the salt and was then run off. Another plan was to terrace a ploughed field and dig a deep trench round it. The field was flooded, and the unploughed subsoil being less permeable, the water holding the salt in solution filtered into the trench. I observed similar processes carried out on the salt marshes round the Bay of San Francisco. This is gradually silting up, and surrounding it are miles of low flats impregnated with sea salt and growing only saline plants. Through these pass shallow delta channels, scoured by the rise and fall of the tide. To reclaim this soil, low earth embankments are raised

round the farms. These are fitted with flood-gates closed by the rise of the tide and opening on its fall. The salt in the soil is washed out by the fresh water of the streams falling into the bay by a process of sluicing such as I have described, and is run off as the tide falls. In the depression between the coast range and the second range of hills artesian wells can be made, and these were used where none of the mountain streams were available. An English Company was working on a salt marsh by the aid of artesian water only; but it was generally considered that it would not be a success, as the amount of artesian water was after all only trifling compared with the area to be reclaimed. The universal opinion in Utah was, that if they once succeeded in covering an alkali field with a crop of any kind, the victory was won. After the land was half cured, they generally covered it with a hardy grass, the most approved being red-top American grass. Beetroot was also said to grow well as an early crop; after that Indian-corn, and other crops by degrees. Tuberous crops grow

By manure and culti- well in the country, and the potatoes are said to be the vation. best in the world. The last method I shall mention was that employed by Brother Fenton, an energetic Devonshire farmer. It happened to be impossible for him to get fresh water to wash the salt out of his fields, and he tried large quantities of manure—20 to 50 tons per acre. Barn-yard manure was considered the best, and as his great object was to keep the surface from the sun, which drew up the salt, he also used litter to cover it. The first crops he covered the ground with were the red-top grass and oats, and he sowed his crops in September, so that the ground should be covered with vegetation when the alkali would be appearing. As soon as by this means he got his first crop of red Timothy grass, he found he had succeeded. Mr. Fenton complained that after partly curing one field he ruined it by trenching and bringing up a saline subsoil. His idea was that the salt was a sort of perspiration of the earth, and, therefore, mostly on the surface, and that by turning up the subsoil he would get a better soil. In India it is certainly the case that a short distance below the surface less reh is found. It may be different in a closed basin like that of Utah, where the subsoil also may become saturated with salt. Utah city is partly situated on a bench at the base of the Wasatch hills adjoining the plain, and at first the farms surrounding it were made on the ground that was not saline. About one-fourth of the land under cultivation was salt, and three-fourths of this had been cured by sheer cultivation, much in the way I have described in the case of Mr. Fenton's farm. For the other fourth, sluicing and irrigation had been available. The cultivation of saline soils is also carried out in other settlements. In most old-settled countries, and especially in India, agriculturists are very conservative in following the practices of their forefathers. In America, where the population is composed of emigrants from all countries, every man brings the methods used in his own, and all sorts of trials are made and the fittest survives. These are made in a new country under new circumstances, and people are not bound by traditional customs, but are anxious to try whatever succeeds in the hands of others, and also make experiments according to their own ideas. These may be crude, but still a vast number of experiments

are made,—not isolated ones by a Government, but everywhere generally by the people themselves—and anything that is successful is hailed as a discovery. Some of the methods I have described as used in America may not always be practicable in the plains of India. To run off the saline water requires a slope and lines of natural drainage that may not be available. It might be possible to run off the salt-impregnated water into absorption wells, thus returning the salt to its natural destination, the underground water. It is a law that a well will absorb as much water without raising its level as it would give out without sensibly lowering it. This means has been used in some

By arboriculture.

cases to get rid of liquid sewage, but was found to poison the wells. The plantation of trees is also proved to be a very efficient means of cure. The kikar is well known as capable of flourishing in such soils. They not only assist in moderating excessive evaporation by shade, but they also absorb and remove a certain amount of salt from the soil. As the alkali exists chiefly in the surface soil and in much less amount at a small depth, trees may grow readily where annual crops could not. The latter have their rootlets only in the surface soil, and are poisoned by the excess of salt; while the roots of trees extend deeper into less saline ground; also plants not only consume a portion of the salt, but they prevent its concentration on the surface. A most conclusive experiment made near the Western Jumna Canal by the Irrigation Department is reported by Colonel Fulton. A piece of utterly useless reh land, for which revenue was remitted, was taken up by the Department and planted with kikar trees. These flourished and a very fine crop of doab grass, 2 feet high, came annually up under the trees, and the efflorescence disappeared. The villagers, seeing that the land was improved and fearing it would be alienated by the new settlement, applied for the restoration of both trees and land, and carried their point in the courts of law. A few days after the restoration the wood was sold to a wood merchant and every tree cut down. At present the doab grass is all gone, and the soil is encrusted with salt. Such an experiment made among American farmers would have excited the keenest interest and given rise to numerous trials of the same.

32. The method of cure by nitrate of lime as a manure, suggested by

Chemical manure.

Dr. Brown, would act in two ways. It would partly serve as a manure favouring vegetation, and in addition it would act on the alkaline and magnesian sulphate by double decomposition, producing nitrate of alkali and sulphate of lime, which last is a slightly soluble salt which is not hurtful to vegetation and would not form an efflorescence. Carbonate of soda would be similarly neutralised, but the sodium chloride would remain unaltered. The natives are well acquainted with this use of nitrous efflorescence, which can be distinguished from the sulphate of soda by its moistness due to deliquescence and by the brown colour and by not efflorescing in fine powder. It consists mainly of common salt and nitrates of lime and soda. This production of nitrate is due to the decomposition of nitrogenous animal or vegetable matter, first producing ammonia, which is afterwards oxidised to nitric acid. An essential condition of the nitrification process is the presence of alkaline carbonate, or carbonate of lime, to fix the nitric acid. For example,

ordinary dung heaps may produce plentiful supplies of ammonia, but no nitric acid. Indeed, nitric acid, if present, is changed by the reducing action of the decomposing organic matter to ammonia. If wood ashes containing carbonate of potash or lime be mixed with the heap, the acid becomes fixed. Artificial nitre beds, called *nitrières*, or nitre plantations, were first introduced by the chemists of France to supply nitre for gunpowder during the wars of the Revolution, when the ports of France were blockaded by the English and imports prevented. Animal manure is mixed with carbonate of lime and wood ashes and frequently watered with urine, which produces much ammonia. This is cultivated for two or three years. In tropical countries the production of nitrates is more plentiful and rapid. A manure of a valuable quality could probably be made by municipalities or by the zamindars themselves by mixing pounded kankar, or even marly soil, with manure and moistening it frequently during one or two hot seasons. If it were moistened with liquid sewage, which would tend to produce more ammonia, the production would be increased. This artificial production is an exact imitation of what takes place naturally in soils in which nitre is produced. In the Punjab nitrates effloresce near villages where the soil becomes impregnated with animal sewage, which undergoes nitrification in presence of the carbonate of lime and alkaline carbonate in the soil. The most plentiful supply is in the soil on the mounds that indicate the sites of old villages. This is the main source of the manufacture of saltpetre in the Punjab. Similarly, near buffalo ponds and watering-places for cattle, where dung is trodden into the soil, nitrates effloresce and are swept up by the zamindars as manure. A similar process no doubt takes place when a field is well manured with animal refuse. The conditions of the production of nitrate of lime in the soil are present, and this may account to some extent for the reclamation of alkali soils by manuring alone. For this purpose animal manures would be far superior to vegetable. In plants there is comparatively little nitrogenous matter, which alone can generate nitrates or ammonia. In Utah a favourite manure is the refuse of slaughter-houses, which would be capable of supplying large amounts of ammonia and nitrates.

33. As regards the uses to which the alkali efflorescence might be put, sulphate of soda can easily be separated by evaporation and forms a useful purgative. It might be possible to utilize those more rich in alkaline sulphate for the manufacture of carbonate of soda for glass or soap work. The average mixture of sodium chloride and sodium sulphate resembles the product of the first step of manufacture of this carbonate, which is done by the addition of sulphuric acid to common salt. By evaporation the sulphate which crystallizes out first in saturated solutions made from efflorescence containing excess of sulphate, can be freed from most of the common salt, and this would resemble the salt cake. The materials for the further reduction, charcoal and lime, would be readily available, the latter from the kankar beds. Certain soils contain carbonate of soda in such quantities that it can readily be separated by the crystallization process. At one time an enquiry was made as to whether the nitre manufacturers defrauded the revenue to any extent by disposing of the alimentary salt left in the refuse saltpetre earth after

extracting the nitre. Samples have from time to time been forwarded to this office, and these were found to contain from 35 to 70 per cent. of common salt. It would certainly be possible and not very difficult to obtain a rather impure alimentary salt by rough crystallization processes, not only from the saltpetre earth, but also from suitable kinds of reh.

THE REH SOILS OF UPPER INDIA, by H. B. MEDLICOTT, M.A., *Geological Survey of India.*

For some time I have intended to publish in the Survey Records a notice of the saline efflorescence known as *reh*, which has been, and will continue indefinitely to be, a subject of the gravest concern to those interested in the welfare of North-Western India. The preceding paper, contributed by Mr. Center, removes the only grounds of hesitation in the matter—as to the adequate illustration of the chemical aspects of the case. The facts of this nature already ascertained by myself and others from the area affected were, indeed, sufficient to establish the case before a jury of experts, and it would have been easy to adduce further illustration from analogous conditions elsewhere; but the men who have to deal with the matter practically are very much the reverse of experts, scarcely even believers, and it is of the greatest importance that the most tangible part of the evidence, the hard facts verifiable by the balance, should be set before them from the very ground which they have to treat. This has been done in a very satisfactory manner by Mr. Center. It only remains for me to supplement his paper regarding some points which it touches on but slightly. The question is truly a geological one, as embracing all the conditions of a complex operation now at work in producing a change in the whole region affected. This has been the difficulty throughout—to induce an apprehension of the situation: that the evil to be encountered is not a fixed obstruction of assignable dimensions and position, but the present active array of natural causes bent upon fulfilling the effects due to conditions that have supervened. In such a case our best efforts may be no more than palliative, unless indirectly, by modifying those conditions, we can mitigate the action of the prime causes.

2. From times far earlier than the date of British occupation, there have been large patches of reh-affected ground in various parts of the Upper Provinces. They are known as *usar* (sterile) and *kabar* (saline) land. As the contention sustained in this and the preceding paper is, that this salt (as such) was not an original constituent of the deposits in which it now occurs, it would be interesting to find any mention of the *usar* lands in remote records of those districts; but it is not at all unlikely that some of them may be of very ancient origin, from the historical point of view. What has recently (within the last 30 years) brought the subject into such prominence was the rapid local extension of reh efflorescence in connection with the great irrigation canals that have been constructed in Upper India. Shortly after my arrival at Roorkee (Rurki), then the head-quarters of irrigation, I was consulted about this plague of salts; not, indeed, as a geologist,

but because I dabbled in chemistry. Samples of soils, sub-soils, and waters were sent for examination. The rough results of this work and of such field observations as I could make in the neighbourhood (which was not a reh district) were brought together in a paper for the Asiatic Society, London (Journal, Vol. XX, p. 326, 1863). This paper and a number of official reports on the same subject were published as No. XLII (1864) of the Selections from the Records of the Government of India in the Public Works Department, as "correspondence relating to the deterioration of lands from the presence in the soil of reh." Many other letters and reports, such as that of the Aligarh Committee in 1878, have from time to time been printed for departmental circulation; but the above is the only information that I know of as available for general reference.

3. So early as 1850, in reply to some questions with samples for analysis, Dr. O'Shaughnessy had supplied facts from which an understanding of the whole case might have been evolved: that the canal water is remarkably pure, although containing an appreciable amount of the reh salts; that the sub-soils of reh land are remarkably free from salts; that the reh is accumulated in the surface soil; and he pointed out that a free use of canal water, with efficient drainage, would certainly cure the evil (*l. c.*, p. 36). No suggestion was, however, made as to how the reh came there: so on this score full play was left for fancy to suit the bias of the speculator. Accordingly, the final decision passed upon these facts by the Board of Revenue is recorded as follows (*l. c.*, p. 8):—"There is, then, positive scientific evidence that the canal water is perfectly pure, and the idea, though it has been started more than once, cannot be entertained for a moment that the salts are deposited by the water used in irrigation. When *reh* appears, it must be that it has previously existed in the soil. For in no lands is the efflorescence of *reh* so extensive or so rank as in those large spaces so common in all the villages of Paneeput and Soonput, where the plough has never been driven; where seed has never been cast; and which, under the name of *kuillur* (answering to the *oosur* of the midland districts), were excluded from the malgoozaree area, for the express reason that they were barren, or, in other words, had too much saline matter in their soil to admit of their being cultivated." This judgment gives a fair illustration of a mischief that too often occurs in India; as must happen where the higher administration is in the hands of men who have grown into it, after a long training in a narrow but very real school of virtual omnipotence, resulting in impenetrable self-confidence; and who consequently never hesitate to undertake and pass decisions upon matters where they are quite unqualified to hold an opinion.

4. Finding that in this matter the local fancy was without rational bounds, and the bias strong in a false direction, I set myself (in the paper referred to) to trace the source of the reh; I pointed out (*l. c.*, p. 40) how the supposition of any store of reh in the ground was untenable, except of course when reh-water had lodged in the upper water table; I proved a case (*l. c.*, p. 43) in which a reh soil had been produced by accumulation from a source no more abundant than the canal water; I stated my conviction (*l. c.*, p. 45) that the old *usar* or *kalar* lands were only special areas of inefficient drainage, lands more or less dependent on evaporation for the removal of surface waters; that, in fact, the

whole phenomenon of reh was superficial, due to the inefficient circulation of the atmospheric waters under extreme climatal conditions.

5. The foregoing brief remarks must suffice as a historical summary of the reh question. We may now, perhaps, assume that the rational explanation of the situation is accepted, or must become so; and proceed to form an estimate of its conditions. My remarks here also must be condensed, referring only to the leading features; a fuller discussion of some particulars was given in my reports to the Aligarh Committee of 1878.

6. The only points to which I need take exception in the views set forth in the preceding paper, are those from which it might be inferred that the state of things so much to be deplored—no less, in fact, than the steadily-advancing conversion of the choicest lands of India into a howling wilderness, such as now obtains over the once luxuriant Mesopotamia—that this is inevitable from natural causes. I have pointed out these weak points to Mr. Center, and he has permitted me to explain them, rather than undertake to do it himself:—It is correctly stated that under certain conditions of surface configuration, of ground structure, and of climate, the local accumulation of saline deposits must take place; the instances given are the great land-locked basins of central North America and Asia. The first condition may be ignored, as it is immaterial whether the surplus waters are concentrated in a local basin or added to the briny deep.

7. The second condition is important. In several passages of paras. 14, 21, and 24 of Mr. Center's paper, the strata forming the plains are described as horizontal, so that the conditions of drainage approach those of a basin, the underground drainage being usually imperceptible. These features of the bhángar land are contrasted (para. 24) with those of the khádar land, where "the river occupies the line of natural drainage of the country, and its deposits are parallel to the line of slope," underground drainage taking place freely; and this, although the khádar valley is truly described as cut out by recent erosion from the old alluvial plain. The small apparent contradiction here is easily explained: the ground surface in the khádar is almost always of very recent sandy deposits, the surface of actual erosion being confined to the present river channel; but there is a real and greater misconception which it is needful to insist upon. It is not questioned that the plains themselves are river deposits; their surface, too, lies appreciably parallel to that of the actual river beds throughout; so it is not intelligible how the lie, or the composition of the strata, can be supposed so different from those of the actual rivers. In the process of land formation by rivers, of which the plains of India afford such a striking example, there does occur partially the production of local basins. From the diluvial zone, where the torrents are discharged from the mountains, to the more exclusively alluvial region of the delta, a partial sorting process takes place in the river deposits. The coarser materials, which in the former position are boulders and gravel, and in the latter fine sand, become thrown down wherever the velocity is checked and along the margin of overflow, thus forming the banks between which the river flows, whether in a single channel or through several distributaries, often at a higher level than adjoining ground separating the channels. These intra-fluvial areas become for the time swamps or temporary lakes in

which some deposition of finer sediments occurs more or less in basin fashion ; but they principally become filled up by the invasion of the river to find a lower level ; when, at least on the line of the new channels, there must be considerable removal and ultimate replacement of any finer sediments. In this way it seems probable that in the growth of the river plains, it is rare for any large area to escape being traversed by a channel of considerable magnitude, or for such areas to be filled up by deposits in which the slope of the river itself is not on the whole maintained. The original *usur* plains may have been such exceptional areas, in which therefore special local obstruction existed to underground drainage. It must, indeed, be admitted that the actual subsoil drainage of the plains is usually imperceptible ; but this seems to be directly accounted for by what is the head and front of the complaint regarding reh : that owing to shallow cultivation, to the sun-baked condition of the surface, and to the absence of any considerable tree vegetation, the rainfall can only soak to a small depth, the remainder running to waste off the surface, or being taken up again by evaporation. For efficient drainage there must be efficient penetration to supply it withal : and, deficient percolation of water through the soil and the sub-soil to the ground beneath is the condition, in default of which the growth of reh is inevitable. It would, of course, be easy to imagine circumstances more favourable to drainage than are those of the gently-sloping alluvial deposits of these plains ; but it seems to me that reh being in part a necessity of the ground structure here, cannot be sustained.

8. There remains the condition of climate, which is the active element of the combination. It is represented (para. 15) as being analogous to that of the typical cases cited, only intensified by heat. Here, again, I have to admit the actuality, but as a charge against nature it is even more untenable than the last. There is contrast rather than correspondence between the physical surroundings of India and those of the typically arid tracts mentioned. In these, aridity is indeed more or less inevitable, for the life-giving moisture hardly approaches them, being to a great extent abstracted from the air currents before they reach these areas. But India is on two sides bounded by a reeking caldron of tropical ocean ; and on the third there is a great air-elevator, flanked by a huge condenser, sending back upon her plains almost every drop of the water that had previously floated over them, repelled to a very large extent by the accumulated heat of the bare and parched ground surface. The endeavour to make these returning waters do duty for rainfall must be a very poor substitute for the due reception and conservation of them in this form in the first instance. It can scarcely be questioned, that left to nature, every foot of our Indian deserts would now have been covered with perennial verdure, and that the present desolation is the result of the devastating proclivities of a worse than savage mankind. It may, too, be affirmed that with time the blessings of nature might be restored.

NOTE ON THE NAINI TAL LANDSLIP (18TH SEPTEMBER 1880), *by*
R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

On Saturday, the 18th of September, at half past one in the afternoon, after more than thirty-six hours of heavy continuous rain, a portion of the hill forming the north-east slope of the valley of Naini Tal fell, sweeping away several houses, and causing the death of 43 Europeans and more than 150 Natives.

Briefly told, the story of the slip is this: On the morning of the 18th, at ten o'clock, a small slip occurred behind the Victoria Hotel, burying part of the buildings in which were some Natives and an European child. A party of volunteers and a working-party from the depôt were soon on the spot, but after a while the greater portion of the latter were withdrawn. After rescuing all that there seemed any probability were still alive, they found that the house was in danger of being washed away by a stream of water, and so turned their attention to the diversion of the stream; and while engaged in this, the great slip came down and overwhelmed them. It is possible that the wash of this diverted stream may have directly contributed to bringing down the landslip, but it seems to me very improbable that it had any such effect; at most it can but have hastened the catastrophe by a few hours.

The part of the hill which has fallen extends up to the old Government House, marked as such on the map. From here the western boundary runs down a little to the east of Marshal Cottage and Charlton; the eastern boundary passes down just to the east of the Victoria Hotel. The mass of debris which has fallen from the hill extends over the level ground at the head of the lake, as far as the Assembly Rooms, of which but the southern end remains standing.

The slip, as it at present stands, stretches in a long, gentle slope, which, omitting irregularities of surface, is not more than 15° up to where the old Victoria Hotel stood; from there it rises in a steep slope of 25° or so, and at the top comes a short space nearly vertical. This steep slope is formed by the small slopes of drier debris which fell after the great one. The total length of the slip, measured horizontally, is about 600 yards, of which over 300 are occupied by the gentle slope, and the remainder are more or less steep.

The hill on the north-east of the lake consists of more or less imperfectly-cleaved clay slates, occasionally showing signs of an initial metamorphism into schist, but for the most part a simple clay slate. The dip is very disturbed, and varies much in different parts in close proximity to each other; but the general dip is to the south-west. The rock also is traversed by very numerous joint planes, which cause it to split up into innumerable fragments under the action of the weather.

Although the whole of the ridge bounding the Naini Tal valley on the north-east is practically one as regards its internal structure, yet, superficially, the south-east portion is very different from the north-west. Looking from the head of the lake, or, still better, from near the old Government House, one cannot fail to be struck by the difference of profile; towards the lower end of the lake the hill sweeps down at an even slope of about 25° from almost the top down to the level of the lake, while nearer the spot where the landslip took place there is a peculiar

bulged appearance of the hill, which makes the slope steeper near the bottom than it is higher up, being occasionally, as above the mission premises, as steep as 35° .

These two areas can be recognised on the map; the even slope near the lower end of the lake is drained by innumerable channels running almost straight down the hill, while on the bulged portion the streams are fewer and their courses not nearly so directly down the hill.

The cause of this bulged appearance I take to be as follows: By the action of the weather the face of the hill gets covered with a greater or less thickness of decomposed rock, which, as already explained, weathers into a mass of small fragments. The rain water, which obtains access to the interior of the hill, for the most part keeps in this decomposed layer and flows down at a short distance from the surface, passing out again lower down in the springs which exist in numbers over this hill, and a large part doubtless percolating downwards reaches the lake without coming to the surface. The presence of large quantities of water among this decomposed rock must, by making it more mobile, assist in producing that phenomenon which is seen in any mass of debris lying at a slope, whether it be wet or dry, namely, the gradual passage of such debris down the slope under the influence of gravity; that some movement of the debris down the slope takes place after heavy rains, seems certain, as is shown by cracks appearing in the surface of the hill side, the lower side of which subsides slightly. Now on a level surface the action of gravity can have no effect in producing any motion, while on a slope the force tending to produce such motion varies directly as the resultant of the vertical force of gravity acting directly down the slope, that is, it varies as the sine of the angle of inclination. Suppose, then, an even slope passing near its base into level ground, and that slope covered with debris; the debris slides slowly down the hill, but on the steeper parts of the slope it must do so faster than near the bottom, where the slope is less and there is the resistance of the debris lying on the level to be overcome, which can only be done by a *vis a tergo*, an impulse from behind. The debris coming slowly down from above and meeting with this obstacle gradually accumulates till it causes a bulging of the slope towards its base, which goes on increasing till the lower part of the hill is so steep that, to use a colloquial phrase, "it is touch and go" whether the hill can stand or not; then a burst of rain heavier than usual comes, the head of water is increased, the force of the water flowing out near the bottom is increased, it begins to wash away the debris near the bottom till the support being removed from below small slips begin to fall; then a few larger, and finally comes the great slip, which brings down the outer crust of half the hill side, leaving a precipitous border round that part from which it has come; finally, the great slip is followed by smaller ones, which leave the hill with a pretty uniform slope from top to bottom for the whole process to begin again. Such I believe to be the history of one of these landslips where there is no stream cutting at the base of the hill; where that is the case, slips may be formed at any time by the cutting away of the foot of the slope.

The slip under consideration has followed very much the course pointed out; the bulging had reached the critical point: all through last rains small slips

occurred; on the 18th a larger one fell, shortly to be followed by the great landslip, which was itself followed by one or two minor ones, though the process of smoothing down the slope has not yet been completed.

Applying this hypothesis to the determination of the question of how much of this same ridge must be pronounced as unsafe and liable to slippage, we must condemn the hill side from a line running upwards from the bank-house to a similar line running down from a little to west of Fairlight Hall, it being all more or less bulged; of this, that part extending from the old landslip to the stream flowing down to the east of the Mission premises must fall in a few more years, but, with this exception, a judicious system of revetment of the torrent beds and a complete system of drainage of the cleared sites will do much to prolong the existence of the present hill side.

As regards the slopes below China, there is but little chance of such a slip taking place; these slopes are the talus of the steep scarp of China, and are continually receiving additions from above, and though on them there may be danger from the large boulders which occasionally fall from China, the slopes pass off so gently into the comparatively level ground at the head of the lake, and are moreover concave rather than convex in profile, that I consider the probability of any of them forming a large slip to be very small indeed.

Many interesting points might doubtless be elicited as to the manner in which the mass moved, were there any satisfactory accounts of eye-witnesses; but such there are not, and for the same reason that it is almost impossible to get a trustworthy account of a great earthquake,—the thing is so sudden and so awful that none but trained observers can keep their presence of mind necessary for making those exact observations which only can be of any scientific use.

The only points which can be satisfactorily established are, that the whole fall must have been over in less than quarter of a minute, and that the Victoria Hotel and Bell's Shop (Racquet Court) were carried along some distance before they fell; in the latter case there is proof of the fact, inasmuch as the ruins are now some yards from the spot on which the building originally stood. As the ground on which both these buildings stood consisted entirely of debris, locally known as 'shale,' which must have been saturated with water after the heavy rains which for thirty hours and more had been pouring into it, it is not surprising that when the wreck of the hill side was precipitated on to it, it should yield as a semi-fluid body would do and float the buildings for some little distance before the actual slip overtook and overwhelmed them. That the whole mass must have been in a semi-fluid state from the amount of water contained in its substance, is shown by the low angle at which it now lies, and by the fact that those who ventured on to the fallen mass immediately after its fall sank up to their knees in the slush, as it has been described.

Doubtless, the point of most scientific interest in connection with this landslip is its bearing on the theory of lake formation by landslips. One of the principal objections raised to the supposition that the barrier at the outlet of Naini Tal, for instance, can be formed by a landslip is, that those slips "possessed of most mobility, from the greater fluidity of their composition, are in the

precise ratio of such fluidity least capable of * * * bearing upon their surface craggy masses of rock, such as I should term erratics" (*supra*, p. 165). The examination of the landslip under consideration disposes of this objection; for though most certainly such 'craggy masses of rock' were not born on the surface of the semi-liquid mass, yet there were numbers such floated in its substance, many of which now show at the surface, several being 9 or 10 feet in length exposed; and I have no hesitation in saying that were this landslip on a larger scale—for it must not be forgotten that compared with several others in the hills around it is insignificant in size—and left untouched by the hand of man, it would, when cut into by rain and streams, show many if not all those features which are supposed to be especially characteristic of a moraine.

As to the question whether the barrier of the Naini Tal basin is a landslip or a moraine, I shall not here enter into its discussion; this, however, I must say, that the profile of the slope to the east of the outlet bears every appearance indicative of a large landslip having fallen there. On the hill side there is no bulging, but a straight sweep down to a comparatively level terrace, through which the stream forming the outlet of the lake has cut down for some distance. Whether the lake was formed by the landslip, or whether this was subsequent to the formation of the lake, I am not prepared to assert dogmatically; but this I believe, that in past times there has been a great landslip from the slopes of the Kalikhan, and that on this old slip are placed the hospital and convalescent dépôt.

The recent slip shows clearly that a large landslip can extend across and fill up a valley, and at the same time may show that mixture of rocks of all sizes which forms one of the chief features of a moraine; and it is not improbable that, under favourable circumstances, it might resist the wash of a stream over it and so form a permanent lake. In the case of Mulwa Tal, one would certainly suppose from the look of the ground that if its existence is not due to a landslip, yet the level of the water must at one time have been raised some twenty or thirty feet higher than it now stands, by a great landslip which has undoubtedly fallen from the hills to the east of the outlet in times which may not date further back than one or two hundred years, and are certainly later than much that geologists would speak of as recent.

But if a lake is to be formed by a landslip, it must not merely be one of those which are everywhere to be seen, caused by the cuttings of a stream into the base of the slope, but rather one of those which take many years and even centuries preparing, as has been the case with this small one at Naini Tal, and which when they fall do not come down in a stream of fragments, but with one great rush, which would carry them right across the valley and raise the surface to such a height that, by the time the dammed-up water reached high enough to overflow, the debris would have had time for the water mixed with it to drain off somewhat, and would have settled down sufficiently to withstand the wash of the stream running over it. Such cases have been known, but the dam has always given way; yet it is not inconceivable that in some cases which have happened in that remote past, of which we have no knowledge but what is written in the rocks, some few barriers so made were able to stand and form what are now known as the Kumaun lakes.

Yet it must always be kept in mind that no theory which can be put forward to account for their formation can be considered satisfactory, unless it also accounts for the absence of similar lakes in other parts of the Himalayas; for it is no explanation to say that this is due to the smallness of the drainage areas which supply the lakes, and the consequent small size of the streams flowing from them, for other portions of the Himalaya are not devoid of small streams, nor can that which flows from Mulwa Tal be called small.

NOTE.

My youngest colleague, Mr. Richard D. Oldham, happening to be in Kumaun at the time, I asked him to give me an account of the disastrous landslip at Naini Tal. The foregoing excellent paper is the result. It is Mr. Oldham's first contribution to the publications of the Survey; and the accurate observation, strict reasoning, and good form it evinces, give high promise of fruitful work to come.

It will not be amiss, on an occasion of such vital interest, to add a few remarks that occur to me, especially as suggested by the report of the Committee appointed by the Local Government to enquire into the condition of the Sherka-danda hill, a copy of which was sent to me officially at about the same time, 'for information.' The portion of the hill marked by the Committee as presently dangerous corresponds very nearly with that indicated by Mr. Oldham; but their observations would seem to have a wider extension, and to involve a larger area of affected ground. Mr. Oldham was only there for a few days, on his way to take up work for the season in Simnour, and he probably confined his attention to the particulars of the event under discussion. I did not instruct, or expect, him to do more than he has done, the Survey not having been called upon for an examination of the ground.

It would be understood from the report of the Committee that the surface cracks, justly regarded as symptomatic of failing ground, occur much beyond the area condemned, also the Committee's description of the geological structure of the hill would be taken in the same sense; it is as follows:—"To the ordinary observer the hill seems to consist of a core of rocky shale, the dip of the strata being to the south-west, at an angle varying from 30° to 50°. This core is covered by varying thicknesses of disintegrated shale and mud, in which are scattered boulders of limestone, and occasionally of trap, the whole of this crust being in its natural state bound together by a luxuriant growth of grasses, shrubs, and trees." It does not appear that this is thought an unusual composition for the crest of a steep ridge, 7,000 feet in elevation. As applied to the dangerous ground, it would exactly suit the conditions described by Mr. Oldham—the decomposed clay-slate creeping down the hill side, carrying with it blocks detached from the occasional outcrops of harder rocks. It is scarcely possible under the circumstances that such a crust could be rock *in situ*, whether an enveloping shell of some unconformable deposit, or a condition, however decomposed, of the rocks described as the 'core.' It can, in such a position, only have been formed from these latter by displacement, being either the remains of an old landslip, or the material in order of active preparation for a slip to come. In the former case the ground may be perfectly safe, in the latter it would be at least doubtful. If, then, this description applies extensively, as might be inferred from the Committee's report, the matter may be worth further consideration; for the premonitory 'bulging,' so effectively detected and described by Mr. Oldham, may not be a necessary part of the performance. In the case of the condemned area, that feature is reasonably ascribed to the resistance so well presented at the base, where the slope tails off into the flat ground at the head of the lake; but where this condition does not obtain, as along the lake shore to the south-east, a crisis might occur without that visible warning, although there would be every reason to expect it to be mild in comparison to what happens when an accumulation has occurred by bulging.

Altogether, it is by no means unreasonable to hope that the practical judgment of the Com-

mittee may be well founded—that, except in the proscribed ground, security can be insured by proper precautionary measures. Mr. Oldham has expressed the same opinion.

In the 30th September number of *Nature*, *a-propos* of the Naini Tal catastrophe, there is a picturesque description of landslips in general. The writer is evidently thoroughly informed upon the subject he treats of, although grievously in error regarding the geological condition of Naini Tal, which is described as on the tertiary rocks. This mistake is unaccountable; for the place is clearly shown on our geological sketch-map of India as inside the Sub-Himalayan boundary. From the foregoing notice it will be plain that the Naini Tal slip cannot be classed with any of the particular cases mentioned in *Nature*. I have seen no fact to suggest that there is any predisposing plane of stratification connected with these slips. The contrary may, indeed, be affirmed; for although the general dip of the strata is stated to be south-westerly, the frequent contortion these slates have undergone almost forbids the supposition of a continuous surface of any extent in a fixed direction, such as is implied by the action in question.

The Naini Tal landslip of the 18th September was in fact, except on the score of mischief, a comparatively small affair, considerably less in magnitude, as mentioned in Mr. Oldham's paper than several others that occurred at the same time in the Kumaun hills.

H. B. MEDLICOTT.

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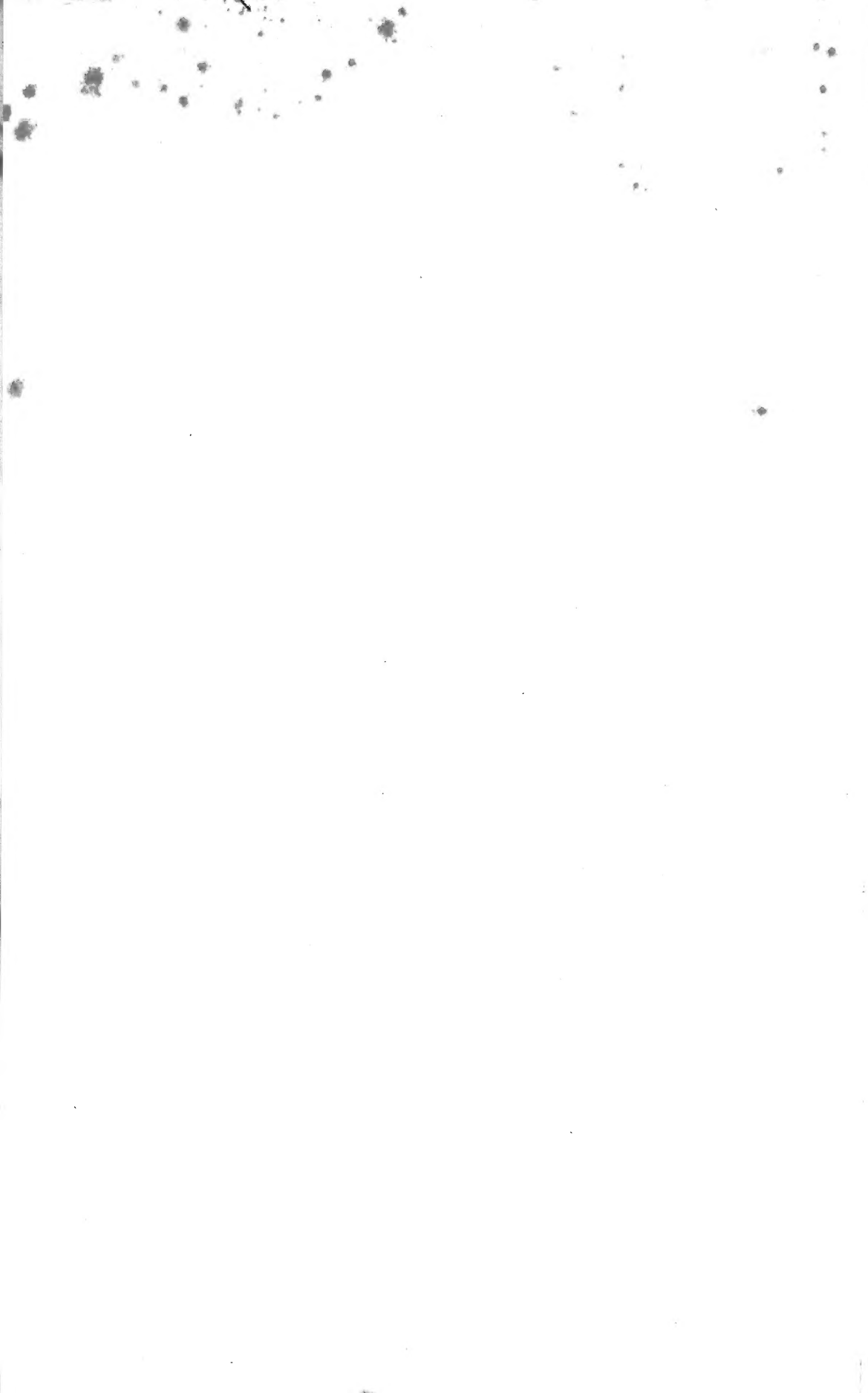
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